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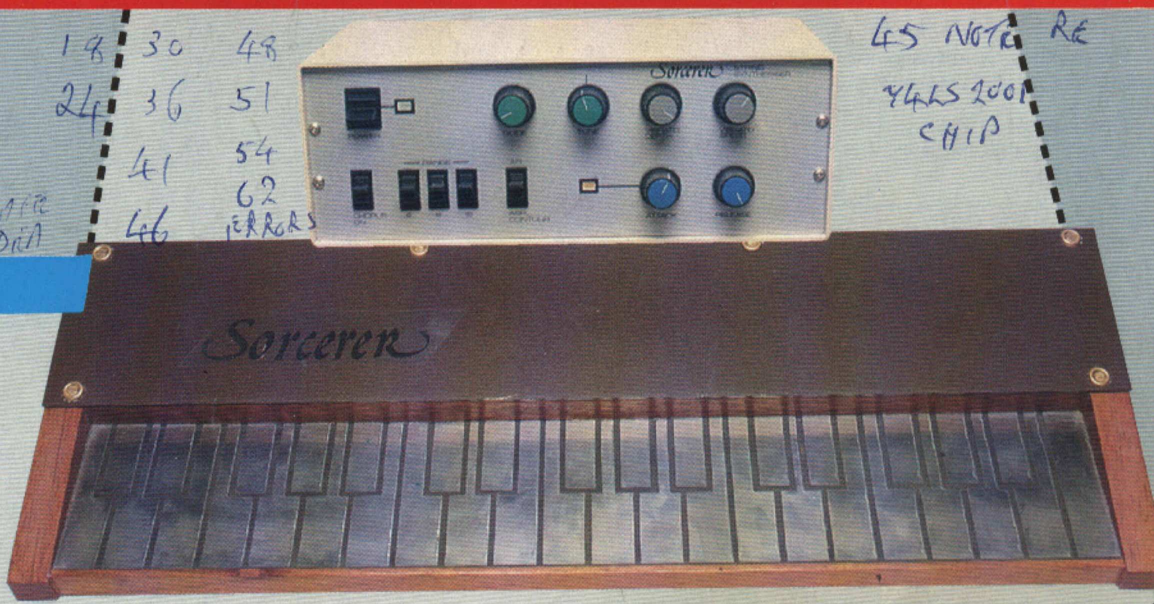


THE SORCERER
STRING SYNTHESISER

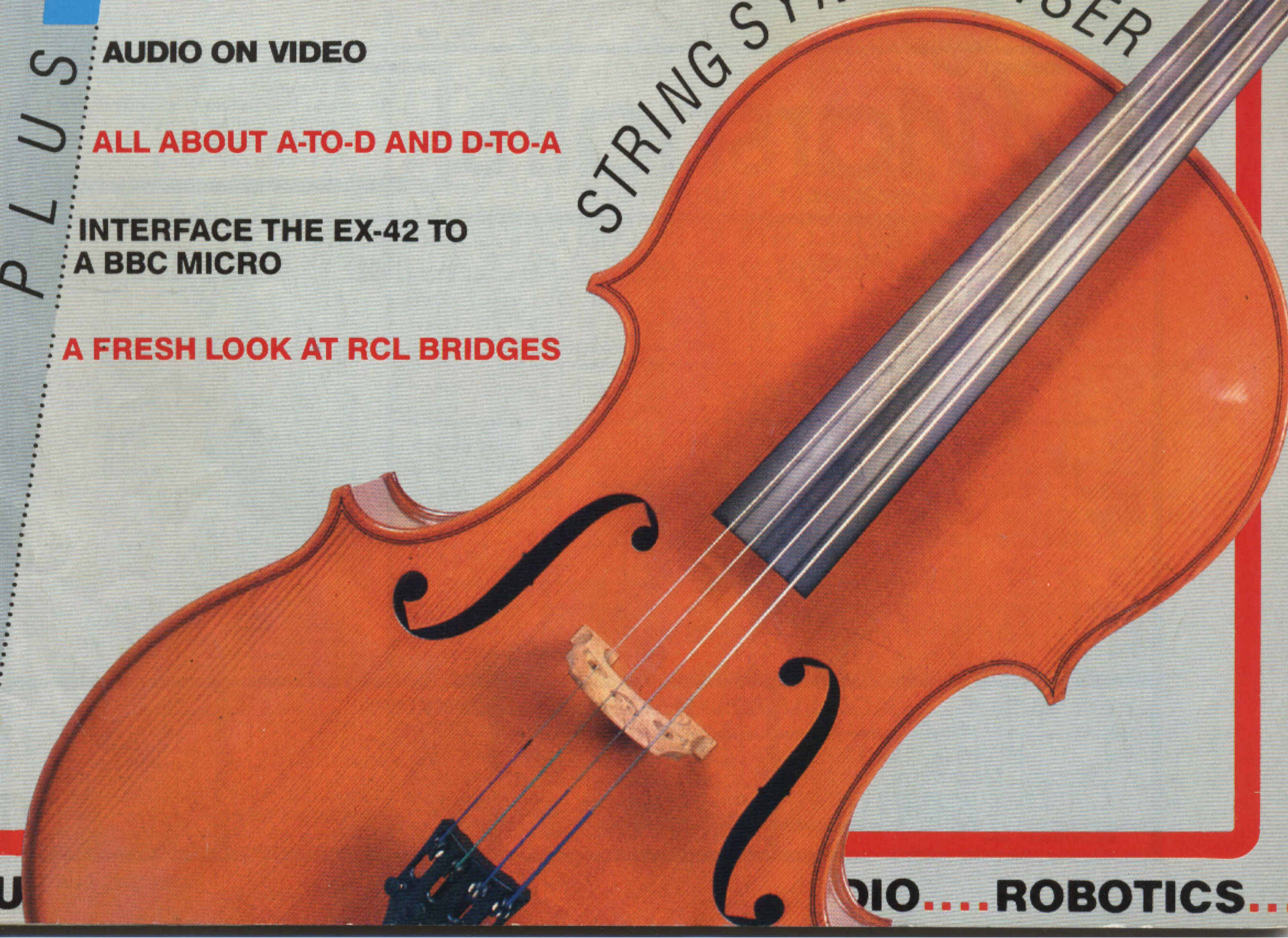
PLUS

AUDIO ON VIDEO

ALL ABOUT A-TO-D AND D-TO-A

INTERFACE THE EX-42 TO A BBC MICRO

A FRESH LOOK AT RCL BRIDGES



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FEATURES

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PROJECTS

ETCETERA

INFORMATION

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DIGEST

TI Announce E-Beam Semi-Custom IC Service

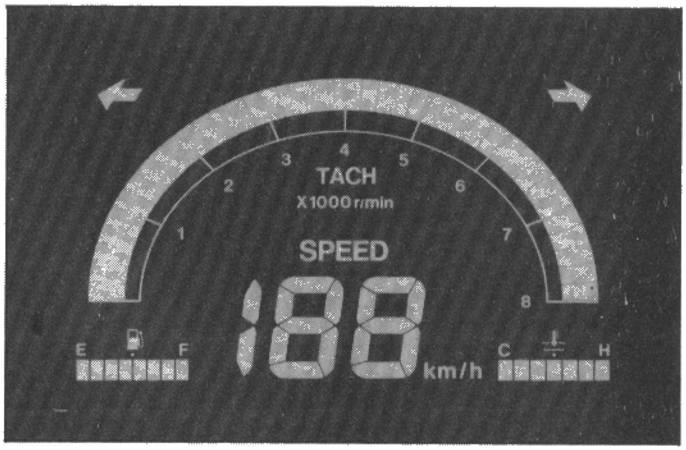
Electronic Equipment manufacturers will soon be able to have small quantities of semi-custom ICs produced to their specific requirements at low cost and in about a third of the usual time. The service will be operated by Texas Instruments from their Bedford headquarters starting in the autumn and will use electron beam lithography, a technology which not previously been available commercially anywhere in the world.

TI will be supplying semi-custom chips based upon 3-micron single level HCMOS gate arrays. Customers will be able to design ICs on their own mini and micro computers using low-cost CAD packages supplied by Texas. Tested prototype ICs should be ready for delivery about two weeks after the design has been completed, a considerable improvement when compared with the six week period usually required by traditional procedures.

The electron beam system is faster because the circuit is literally carved out of a slice of silicon by a computer-guided beam. This takes substantially longer than the usual photographic method, but the time and expense saved through not having to make an elaborate photographic mask more than makes up for this and there is the added advantage that even single chips can be produced economically. This will enable the facility to be used for prototyping as well as for low-volume production, and chips developed using the system can be transferred to standard fabrication plants for later mass production.

TI say that the introduction of this service will enable European electronics manufacturers to produce specialised equipment for low-volume markets and still make a profit. They hope that this will help to insulate the European industry from the problems of fluctuating demand and fierce price cutting which currently characterise the high-volume markets dominated by Japan and the USA.

Texa Instruments Ltd, Manton Lane, Bedford Mk41 7PA, tel 0234 - 63211.



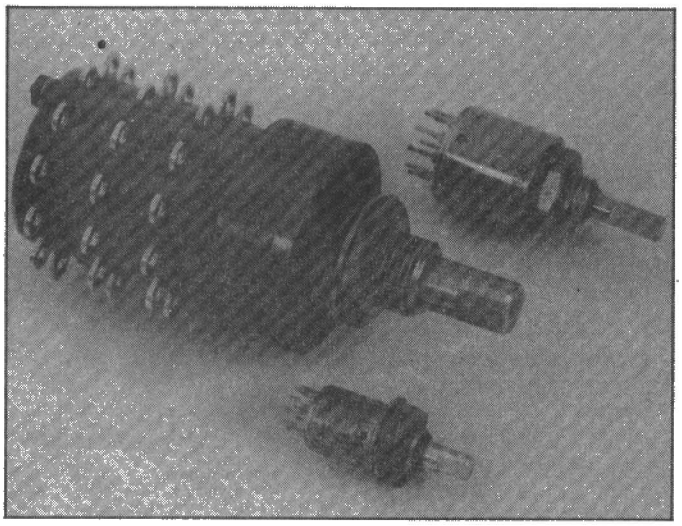
Liquid Crystal Shutter

Epson have developed a liquid crystal display which is normally opaque but becomes transparent when activated. With a light placed behind it the unit combines all the advantages of LCDs with high brightness, and the manufacturers also expect it to find applications as a shutter in specialist cameras.

The display is known as the Black Shutter and uses a black dye which has very high light absorption qualities. This removes the need for the two polarisers found in conventional twisted nematic LCDs. The display has a contrast ratio of up to 25 to 1 and is available in two versions, one designed for use in cars which has a permitted temperature range of −30°C to +80°C and the other designed for use in consumer goods and rated for use over the range −10°C to +60°C.

Conventional LCD displays offer low consumption but emit no light and have a restricted viewing angle. The back-lit Black shutter not only offers high brightness which allows it to be seen under any lighting conditions but also has a wide viewing angle and still uses little power. Epson anticipate applications in a wide range of consumer goods and in large indoor and outdoor display units such as those found at railway stations, airports, sports grounds, etc. The Black shutter is already being used both in the UK and in Japan for motor car instrumentation.

Epson (UK) Ltd, Dorland House, 388 High Road, Wembley, Middlesex HA9 6UH, tel 01-902 8892.



Enclosed Rotary Switches

Dean Electronics have introduced a range of rotary selector switches which are fully enclosed and can be sealed to provide protection from water, contaminants and most solvents. They are available in three sizes in a wide variety of contact arrangements and the manufacturers claim that they all meet or exceed the relevant military specifications.

The 3600 series switches are the largest in the new range at 1" diameter and are available with from one to six poles and from four to twelve ways. The indexing varies with the number of positions, being either 30°, 36°, 45°, 60° or 90°. The positions are thus spaced evenly around the rotation of the switch and an adjustable end-stop is not necessary.

The 1800 series switches are 0.5" in diameter and are single pole with from two to sixteen ways. Three different indexing angles are available and they can be supplied with or without adjustable end-stops.

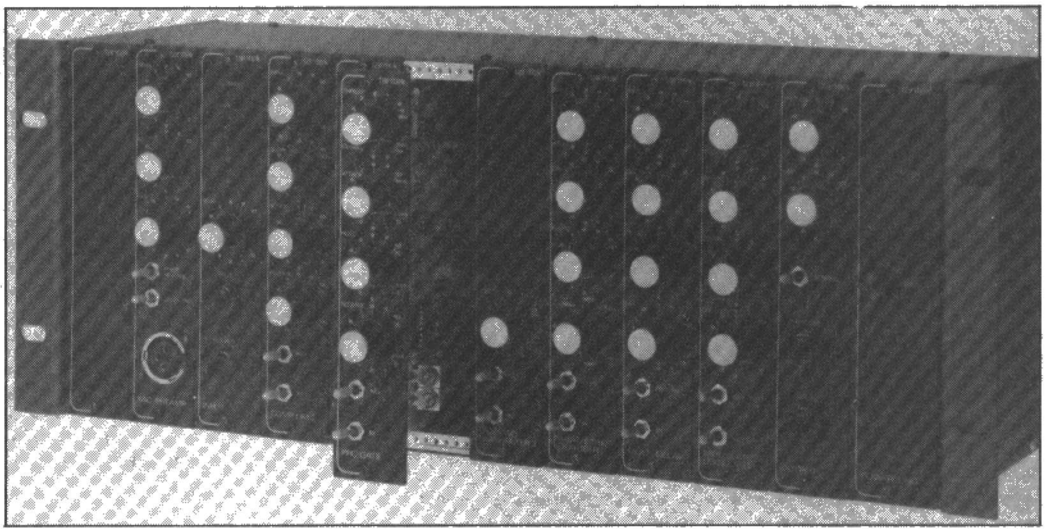
The smallest switches in the range are the 1500 series at 0.32" in diameter. They are available with two different indexing angles and have fixed end-stops. A number of switching arrangements can be accomodated and a printed circuit disc in the base of the switch allows BCD and other coding systems to be implemented.

All three sizes in the range have self-cleaning roller bearing contacts for high current carrying capacity and pure silver contacts to give low resistance. Hardened steel sprockets and ball bearing detent mechanisms ensure a positive detent action and the rotors and stators are moulded from diallyl pthalate thermosetting plastic to give excellent electrical and mechanical properties. The manufacturers claim a mechanical life in excess of 100,000 cycles.

The switches meet or exceed the applicable MIL-S-3768, Style SR20 requirements and can be supplied with an internal seal to provide full protection in harsh environments. They are expected to find applications in military equipment, in aircraft and in commercial fields such as industrial controls and medical electronics.

Dean Electronics Ltd, Glendale Park, Fernbank Road, Ascot, Berkshire SL5 8JB, tel 0344 - 885 661.

Modular Audio Processing System



Tanrak is a 19" subrack assembly which accepts a range of plug-in audio processing and effects modules. It is aimed at musicians, smaller studios and others on a tight budget, allowing a system to be built up gradually as finances allow, and to reduce costs still further the rack and modules are available in kit form.

Eight modules are currently available, a compressor/limiter, a parametric equaliser, a multi-delay unit which can be used for chorus and other effects, a noise gate, a dynamic filter, a modulation osciallator and input and output modules. Other modules are promsied including an infinite flanger and a microphone preamplifier. The modules slot in to a 4U (7") high 19" subrack which can house up to eleven of them plus a DC power supply.

The system is designed so that signals enter the system via a front panel jack on the input module, are processed by switching in and adjusting other modules as required, and then leave via another front panel jack on the output module which also has a headphone monitor socket. When used in this way the system can handle mono signals only, but each module has a series of jack sockets which protrude through the rear of the subrack and can be used as a patchbay to permit stereo and other arrangements in which modules handle different signals. The noise gate, noise filter and compressor limiter are stereo modules so only one of each would be needed for stereo operation. Other units would have to be used in pairs.

The modules all have a high specification and have been optimised for operation at −10dBv, although all will work quite happily at 0DBm. The power supply provides ±12V DC at 500mA which is also available via a DIN socket on the rear panel to drive other equipment or a slave rack should eleven modules not be sufficient. The socket can also be used to plug in a supply from an external power unit.

The modules have black anodised front panels with orange lettering and matching knobs and switches. The aluminium subrack has a textured stove finish and can be supplied with a matching set of metal cover plates if it is to be used free standing. Blanking panels are available to cover unused module positions.

The subrack costs £47.95 ready built (backplane assembled but supplied flat ready for screwing together) or £33.95 in kit form. The power unit costs £42.95 ready built or £33.95 in kit form and the other modules range in price from £46.95 ready built for the input and output models (£32.95 in kit form) up to £110.95 for the multi-delay unit (£79.95 in kit form). All prices include VAT and postage. For those who are little worried about tackling kit construction, the manufacturers also offer a get-it-going service which will repair any faults on a completed kit for a standard charge of 20% of the kit price.

For more information and detailed specifications of the various modules, contact Tantek Services, Enterprise House, Elder Way, Stevenage, Hertfordshire SG1 1TL, tel 10438 - 726155.

Budget Sound Level Meter

Testing for compliance with noise legislation requires expensive Type 1 sound level meters, but there are many applications where the sophistication of such instruments is unnecessary. With this in mind, Castle Associates have introduced a general purpose noise meter which is designed to offer accurate, repeatable noise measurements at low cost.

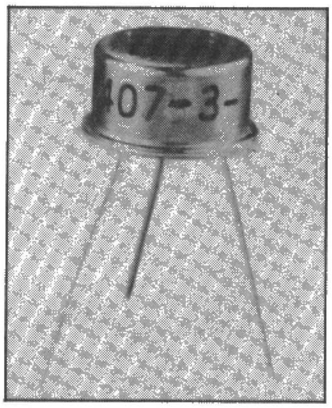
The GA301 Noise Survey Meter is a Type 3 instrument which covers the range 35-130 dB(A) in 10dB steps. The result is displayed on an analogue meter and a switch selects either fast or slow response. The specification exceeds the requirements of British Standard 5969 for Type 3 sound level meters and also meets or exceeds the requirements of the equivalent foreign standards.

Suggested applications for the GA301 include the balancing of noise levels in different areas covered by large public address systems and demonstrations of the physics of noise in schools and other educational institutions. The meter could also be used to make initial surveys of noisy environments and for routine checking in factories, etc, allowing expensive Type 1 meters to be used only where there are definite grounds for suspecting a breach of the regulations. Any occupied area providing a reading within 3dB of the accepted limit (usually 90 dB(A) in this country) should be considered suspect and checked with a Type 1 instrument.

The GA301 is housed in a steel case which measures 175 x 54 x 60mm. A calibration unit is also available. As a special introductory offer, Castle Associates are offering a kit which consists of the GA301, the calibrator and accessories in a small attache for £135.00, the usual cost of the meter and the calibrator alone.

Castle Associates Ltd, Salter Road, Cayton Low Road Industrial Estate, Scarborough, North Yorkshire YO11 3UZ, tel 0723 - 584250.

Thermally Compensated Infra-Red Detector



Eltec Instruments have developed a pyroelectric infrared detector with a unique crystal arrangement which compensates for unwanted signals generated by fluctuations in the ambient temperature of the detector housing itself.

The Model 407 consists of two lithium tantalate sensing elements and a JFET source follower housed in a standard TO-5 transistor package with optical filter. One centrally located active sensing element is exposed to infra-red radiation entering through the detector optical filter window while the second compensating element is shielded from outside radiation. The elements are connected electrically in a parallel opposed configuration which produces cancellation of signals received by both as a result of thermal changes in the detector housing.

The 407 has an optical bandwidth of 1.5 to 1000um and an operating voltage range of 3-15V. The recommended operating temperature range is -10° to +50°C. Eltec say the device will allow reliable sensing in applications where temperature fluctuations previously presented a problem, and expect the 407 to be used in industrial control systems, infra-red telescopes and robotics as well as in a number of other applications.

Eltec Instruments Sa, Neugutstrasse 4, 8304 Wallisellen, Zurich, Switzerland.

Instant Thermal Joints

Charcroft Electronics are distributing a thermal jointing film which can be used instead of liquid thermal compound when assembling power semiconductors onto heatsinks. The film is coated on each side with a compound which remains solid at room temperature but turns to a liquid when heated, thus wetting the thermal joint each time the equipment is operated.

Charcroft claim that Crayotherm offers a high electrical resistance combined with a high thermal conductivity and that it avoids the mess and contamination associated with liquid compounds. Unlike conventional elastometric insulators, Crayotherm will not harden with time and component failure caused by reduced heat dissipation across the joint is eliminated.

The film can be supplied in roll or sheet form or pre-cut to fit popular semiconductor packages such as T03, T036, T066 and D04. Charcroft say they will gladly supply free samples to readers.

Charcroft Electronics Ltd, Charcoft House, Sturner, Haverhill, Suffolk CB9 7XR, tel 0440 - 705700.

● Electrovalue have issued the June 1985 edition of their mail-order catalogue which remains valid until the end of September. The new catalogue has 48 A5 pages, four more than the previous issue, and includes an expanded range of test gear as well as other new lines and all the usual items. Electrovalue Ltd, 28 St. Judes Road, Englefield Green, Egham, Surrey TW20 0HB, tel 0784 - 33603.

● *Impectrom are distributing a full-colour, 14-page, A4 catalogue from Sharp which describes their range of LEDs. The catalogue provides full technical information on over 500 LED indicators, arrays, backlights and alphanumeric and symbolic displays, and copies are available free-of-charge from Impectron Ltd, Foundry Lane, Horsham, West Susex RH13 5PX, tel 0403 - 50111.*

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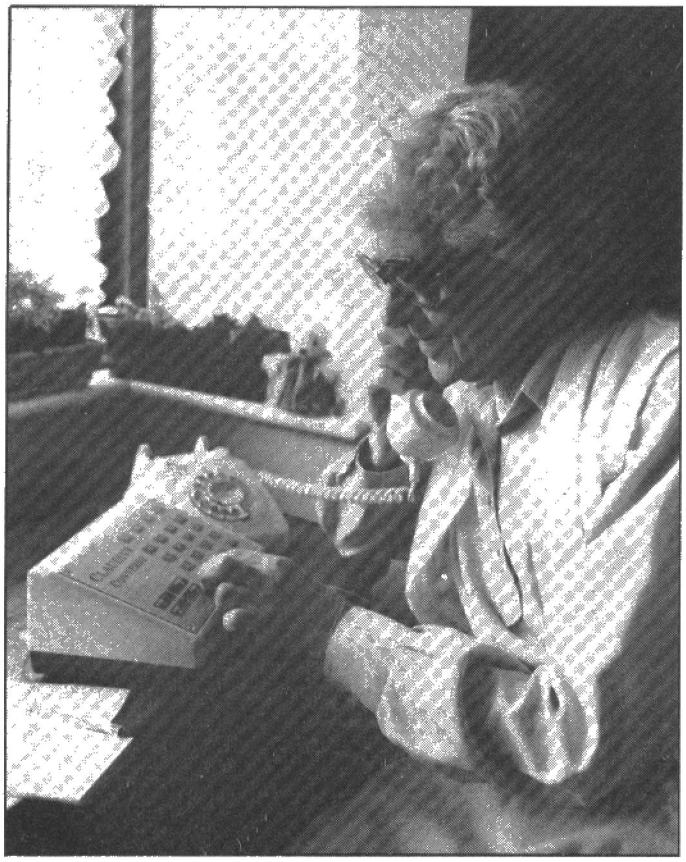


Aid For People With Speech Impairments

Claudivs Converse is a speech synthesiser which can produce words, phrases and even sentences at the touch of a button. It has been developed by British Telecom to help people who cannot speak, and can be used both on its own and in conjunction with a telephone.

Claudivs stands for Calling Line Announcements Using Digitally Integrated Voice Synthesis, but is also named after the Roman emperor who had a speech defect. Up to 64 phrases selected by the user are recorded and then stored in digital form in the machine. This allows it to reproduce both male and female speech and to cope with any language.

A built-in lodspeaker allows Claudivs to be used on its own for normal conversations but it can also be directly connected to a telephone line. When so connected, four red buttons provide instant dialling of ambulance and other emergency service numbers and a message including the caller's home address is automatically sent.

About 120 of the units are already in use by BT customers and more are on the way at a cost of about £250.00 each. One of the first users of the device is Beattie Brooks of Littlehampton, Sussex, who lost her voice after a throat operation two years ago. In spite of her disability she is the local secretary for the RSPCA and raises money for them by making soft toys. Many of the phrases recorded on her machine were chosen in conjunction with a speech therapist to help her in this work.

British Telecom PLC, 81 Newgate Street, London EC1A 7AJ, tel 01-356 6591.

● Does not having your own mains adaptor make you blue, are you red with rage because your adaptor doesn't work or just green with envy because your friend's does? Then despair no longer, for First Castle Components have launched a range of low voltage mains adaptors in colours to suit your every mood. Whether they will also match your every equipment we do not know because the press release doesn't contain much technical information, but if you write to First Castle Components Ltd, 263 Church Road, Thundersley, Essex SS7 4QN, they'll probably give it to you in black and white.

PCB Service

We must make our humblest apologies to readers who have experienced long delays on orders for PCBs. Due to a factory move and a reorganisation, many boards are temporarily out of stock. They will come back on stream gradually as the new system gets up and running.

Not all boards are out of stock, but many of the newer ones are and epecially those that have proved popular. The boards from this issue and the previous issue are among those affected.

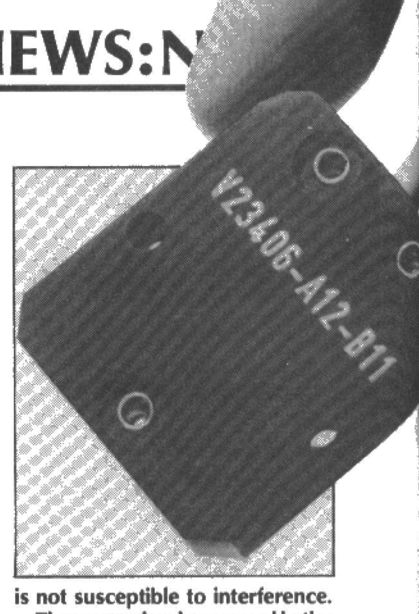
If you've been waiting for some time and you've decided that enough is enough, we will, of course, give you a refund. On the other hand, if you're prepared to wait, you will get your boards eventually.

● Electron Electronics have sent us a copy of their mail order components catalogue which covers 44 A4 pages and lists over 3000 items. Books, tools and test gear are included along with a wide range of more general components and copies cost 50p (free to schools, colleges, etc.) from Electron Electronics, 62 High Street, Croydon, Surrey CR0 1NA.

● **Scicon have installed a computerised information retrieval system in the House of Lords Library at Westminster. The system is called POLIS (Parliamenatary On-Line Information System) and will provide an index to the publications held in the library. It will be updated twice weekly. It is run on a Sperry 1100/61 at Scicon's computing centre in Milton Keynes and is similar to the system installed by the same company in the Commons five years ago exept in that it has no external users.**

○ *The British Kinematograph, Sound and Television Society have given their 1985 Charles Parkhouse award to Neve Electronics for the design and development of the DSP console, the worlds first comprehensive, all-digital sound mixing console. The award is shared with CTS Studios in Wembley who were the first to use the DSP.*

Constant Magnetic Field Sensor



Siemens have developed a sensor which will detect constant magnetic fields, unlike conventional sensors which work on the induction principle and will only detect changing fields. The sensor can detect the changing influence of the Earth's magnetic field as it is moved about and can therefore be used in navigation and other position sensing systems.

The heart of the sensor consists of two iron-core coils wound on a soft magnetic material which has an extremely low remanence. The inductance of the two coils changes in accordance with their respective positions in relation to the Earth. The output of the coils is fed via a three wire cable to external electronics which measures and compares these changes.

The sensor itself is housed in a plastic case which measures 30 x 34 x 7mm and is described as rugged and unaffected by high temperatures. The detection system used ensures that the sensor is not susceptible to interference.

The sensor has been used in the 'autoscout' traffic navigation system which is currently undergoing trials. It provides position information by continuously measuring the angle between the longitudinal axis of the vehicle and the Earth's magnetic field. Other suggested applications include oil exploration where it can be used to detect deviation of the drill from its intended path and military systems for locating individual soldiers.

Siemens G, Dept N SI Komp Dm, Hofmanstrasse 51, 800 Munich 70, tel 089-722 62134.

NEWS: NEWS: NEWS:

Events Diary

Personal Robotics Conference & Exhibition — July 2-4th
West Centre Hotel, London. For details see July issue or 'phone 01 - 236 4080.

Programming In C: A Hands-On Workshop — July 2-5th
Cafe Royal, Regent Street, London. For details see July issue or contact ICS at the address below.

Leeds Electronics Show — July 3-5th
University of Leeds. For details see June issue or 'phone 0799 - 26699.

Cable '85 — July 9-11th
Metropole Hotel, Brighton. For details see July issue or contact Online at the address below.

Personal Computer World Show — September 4-8th
Olympia, London. For details see July issue or 'phone 01-486 1951.

Interconnection Europe '85 — September 10-12th
Cumberland Hotel, Marble Arch, London. For details see February issue or 'phone 0582 417438.

Programming In C: A Hands-On Workshop — September 24-27th
Venue to be announced. For details see July issue or contact ICS at the address below.

Computer Graphics Course — September 24-27th
Venue to be announced. For details see July issue or contact ICS at the address below.

Semiconductor International — October 1-3rd
NEC, Birmingham. Exhibition and conference covering the latest in semiconductor design, assembly and testing. For details contact Cahners at the address below.

System Security — October 2-3rd
Tara Hotel, London. Conference aimed at technical and managerial staff concerned with security in data systems. Cost is £465.00. For details contact Online at the address below.

Internepcon UK — October 8-10th
Metropole Hotel & Brighton Centre, Brighton. Exhibition and conference aimed at electronic manufacturing engineers and management and covering the latest development in electronic design, manufacturing and testing. For details contact Cahners at the address below.

Technology Engineering Fair — October 8-11th
NEC, Birmingham. An event which combines the Design Engineering Show (DES), Electronics in Engineering Design — The Interface (EED), and The Factory Efficiency Show (also known as PEMEC). The DES is intended as a showcase for new design engineering ideas while EED places particular emphasis on interfacing mechanical and electronic systems. PEMEC is aimed at factory managers and will show a wide range of factory maintenance, automation and health and safety equipment, etc. Each show has its own conference programme and the organisers will be operating a computer lcation system to help visitors find specific products quickly. For further details contact Cahners at the address below.

Computer Graphics '85 — October 15-18th
Wembley Conference Centre, London. Exhibition and conference which includes a number of one and two day seminars and modules on topics such as engineering and CAD, computer animation, holography and mapping, planning and construction, etc. The event includes the Computer Animation Film Festival on the evening of the 17th. Costs range from £150.00 for one-day seminar up to £495.00 for the full four days. Contact Online at the address below.

Addresses:
Cahners Exhibitions Ltd, Chatsworth House, 59 London Road, Twickenham, Middlesex TW1 3SZ, tel 01 - 891 5051.
ICS Publishing Company (UK) Ltd, 3 Swan Court, Leatherhead, Surrey KT22 8AD, tel 0372 - 379211.
Network Events Ltd, Printer Mews, Market Hill, Buckingham MK18 1JX, tel 0280 - 815226.
Online Conferences Ltd, Pinner Green House, Ash Hill Drive, Pinner, Middlesex HA5 2AE, tel 01 - 868 4466.

READ/WRITE

Newrad

Dear Sir

ETI in conjunction with John Linsley Hood produced what appeared to be an excellent amplifier design. I would imagine that the design appealed to many electronics hobbyists and possibly like myself many of them were delighted that Newrad Instrument Cases was to supply a complete kit of parts. You will appreciate the major problems of electronics as a hobby: namely the supply of components of a suitable quality and the frequent inability to obtain an adequate professional enclosure for the finished item. I am always pleased when manufacturers such as Newrad Instrument Cases produce the parts in one complete package.

As an electronics hobbyist I could easily understand the difficulties experienced by Newrad Instrument Cases in obtaining parts, effecting changes in circuit design, and also anticipating the number of kits they would need. Even the greatest degree of understanding and patience wears a little thin after a year. I have telephoned Newrad Instrument Cases on numerous occasions and certainly over the last few months have been met by an Ansaphone machine during normal business hours although I admit that my letters have been answered promptly. It would also be worth noting that Mr. Phillips sounds a very reasonable person on the telephone but has had difficulty in fulfilling his promises particularly in respect of time, and has needed reminding on occasions.

The final promise for completion of this kit in respect of the item that Newrad should have found the most easy to produce, namely the case, promised for three weeks delivery some two months ago has finally worn my patience out. I wrote to Newrad Instrument Cases two weeks ago by recorded delivery letter threatening legal action if my money had not been returned by Monday, 3 June. It would appear that Newrad Instrument Cases are uninfluenced by the right and proper use of the legal system and before proceeding further I felt I should inform you. I appreciate that you have no direct legal responsibility in the respect of the supply of the components by mail order but I am sure that you will accept a large moral responsibility for recommending Newrad Instrument Cases as the sole supplier for a product initiated by John Linsley Hood and Electronics Today International. I would imagine that a large number of your readers have ordered such kits from Newrad and, like myself some years ago, are probably not in a position to take on the companies who dishonour their public agreements. I am in a better position today to meet such people head-on and although I have no desire to be a martyr I am fully prepared to take this case to its limit and demonstrate that large numbers of people cannot be treated so shabbily.

I have spoken with my solicitor but am prepared to withold instructions until the next publication of ETI in order that you may publish this letter in part or in whole and give me a much better idea of the scale of the problem that Newrad have created. I have no idea how many people are involved but, expressed in round figures, £100 or £250 units tens of time over, invested for the period of about a year, would come to an enormous sum of money. I would certainly welcome your own comments re the above and should you decide to publish the letter I would like to hear from anybody else in a similar situation to assess the full nature of the best.

Yours faithfully
Dr. P.A. Joiner
Caithness.

We have decided to print Dr Joiner's letter in full because, despite assurances from Newrad that the problems with the Linsley Hood MOSFET amplifier would be cleared up by now, we are still receiving complaints. We accept that we have a moral responsibility to our readers who may be being ill-served by Newrad despite having received an implicit recommendation from us to deal with the company. In fairness, I should point out that the level of complaints has dropped off since Chris Phillips of Newrad gave his assurances. I should also point out that we can continue to recommend Newrad's products (including the JLH amplifier) without reservation. They are undoubtedly of high quality and good value. However, such recommendation is undermined if the products are unavailable, for whatever reason. Like Dr. Joiner, we urge any other readers still awaiting delivery of the JLH amplifier kit (in whole or part) to write to us (please don't phone) so we can gauge the extent of the problem, if problem there be. Armed with this information, we will be able to approach Newrad, if necessary, from a strong position in order to discharge our moral responsibility. Regrettably, the Mail Order Protection scheme — under the terms of which it is possible to claim compensation for goods paid for but not received — only applies in the case of a mail order supplier ceasing to trade. To the best of our knowledge, Newrad are not in this position. — Ed.

Seeing The Light

Dear Sir,

In my original article ('Large Digit Scoreboard', ETI, May 1985), I mentioned the trouble I experienced with lamps blowing and taking their Triacs with them. I have since found a solution, which is applicable to any Triac — controlled lamp project.

There are a number of situations where a Triac is used to control mains power to a bank of lamps, eg. the scoreboard, disco light shows, etc. In such situations, if a lamp blows it can form a momentary short circuit and the resulting current surge destroys the Triac. Typically, the Triac will go short circuit, and the other lamps in the bank will be permanently on.

The solution to this involves putting a current limiting resistance in series with the lamps, but for practical purposes a limiting resistor will be very wasteful of power. The answer is to wire the bank of lamps in series instead of

parallel. In this case, when a lamp fails, the others in the string act as a limiter and protect the Triac.

Naturally, the string of lamps acts as a potential divider, so each lamp must operate from a lower voltage than normal, much the same way as for a string of Christmas tree lights. If, for example, the bank contains five lamps, each one should be rated at 250/5 = 50V operation. A range of pygmy bulbs with ordinary bayonet bases called Sign bulbs is available from various suppliers. They are rated at 15W, with a variety of operating voltages, and selecting from these should fill most requirements.

This idea is adaptable even to applications where a Triac drives a single bulb. Providing it is not a drawback to replace the single bulb with a cluster of lower voltage bulbs, the modification can be made and the Triac duly protected.

Yours sincerely,
Ken Wood,
Ipswich.

Not so much a case of 'If at first you don't succeed, Triac again', more a case of a light subject treated series-ly . . . Ed.

ETI

THE REAL COMPONENTS

This month's topic is amplifiers in small packages, and as usual, John Linsley Hood has it all wrapped up.

In the late 1950s, it occured to one of the semiconductor manufacturers in the USA that it would be possible to put together complete pieces of simple circuitry on a slice of P-type mono-crystalline silicon. The necessary components could be formed by suitable masking and diffusion processes.

For example, a resistor could be made by diffusing in a zig-zag track of fairly lightly doped N-type material, with a connector pad at each end (Fig. 1). A capacitor could be made by oxidising a small area of the silicon and putting a layer of evaporated aluminium metallising over

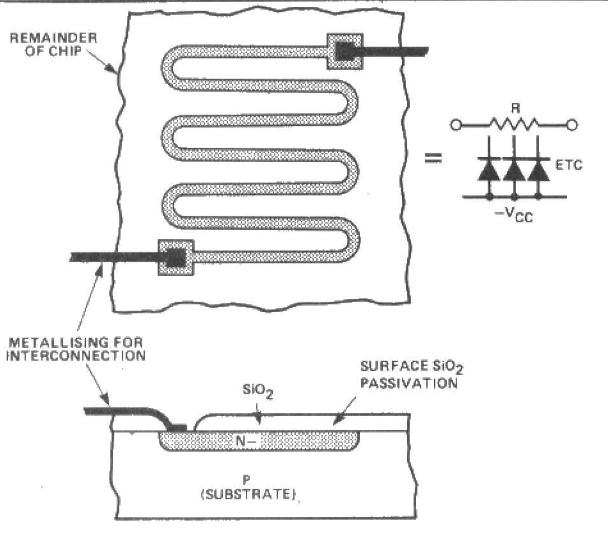


Fig. 1 A resistor formed by diffusing a zig-zag track of N-type material into a P-type substrate.

the top of it, with a buried N-type layer underneath as the other plate (Fig. 2). NPN and PNP transistors could be made as shown in Figs 3 and 4. However, there are snags.

Resistors and capacitors take up a disproportionate amount of room on the chip surface, unless the values are pretty small, and it is very difficult to get the values within limits closer than ± 30%. In addition NPN transistors are not likely to be very good ones in terms of noise, current gain, or breakdown voltage because they have to be made by three separate sequential diffusions (an N-type impurity, followed by a P-type impurity, followed by another N-type), each of which adds to the total impurity concentration within the collector, base and emitter region.

In the case of the PNP transistors shown in Fig. 4, the only one which is at all reasonable in performance is the one which can use the substrate (usually connected to the »ve supply line) as its collector. If the circuit doesn't allow this, it is necessary to use the lateral construction in which the base region is formed by masking off a narrow strip, with the emitter and collector regions diffused into the N-type zone as close together as possible. Even so, and with the best mask technology in the world, the current gain of such a transistor may be only 5–10 and its HF response will be pretty miserable.

Within these limitations it was possible to make some useful circuit blocks, and the circuit and mask layout designers learnt from their experience. They certainly needed to, since some of the early ICs, from my painful recollections as a user, left a lot to be desired in both performance and reliability.

Modern circuit techniques and circuit designs have transformed this situation, and my honest opinion now is that, if there is an IC which will do what one needs, then it is pointless to try to do the job with discrete components other than in a few specialised applications. After all, some of the best electronic circuit designers in the world work for the IC manufacturers.

Operational Amplifiers

These, normally known just as op-amps, are the most common form of IC which the user of linear circuitry will encounter. They can be regarded simply as gain blocks

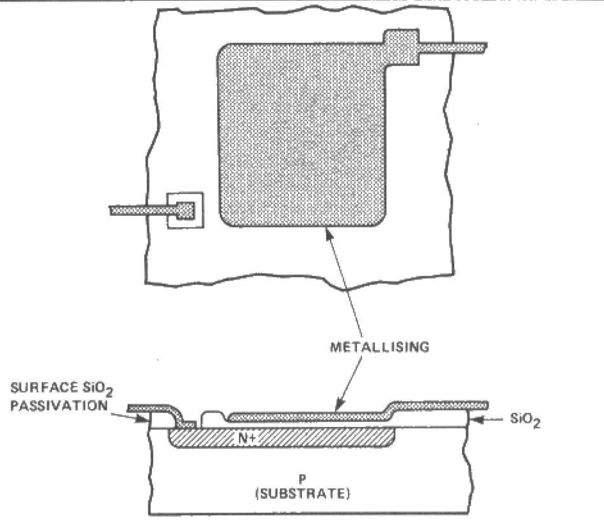


Fig. 2 A capacitor consisting of an N-type diffused layer separated by an area of oxidisation from a layer of aluminium metallising.

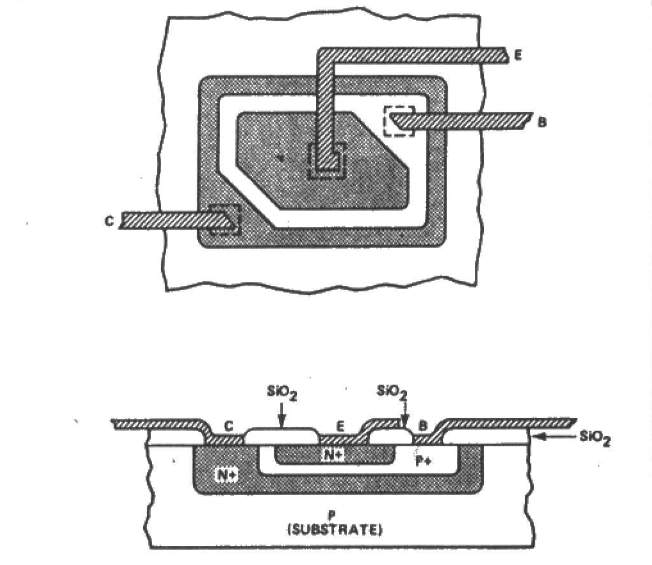


Fig. 3 An NPN transistor formed by diffusing three layers one on top of another into a P-type substrate.

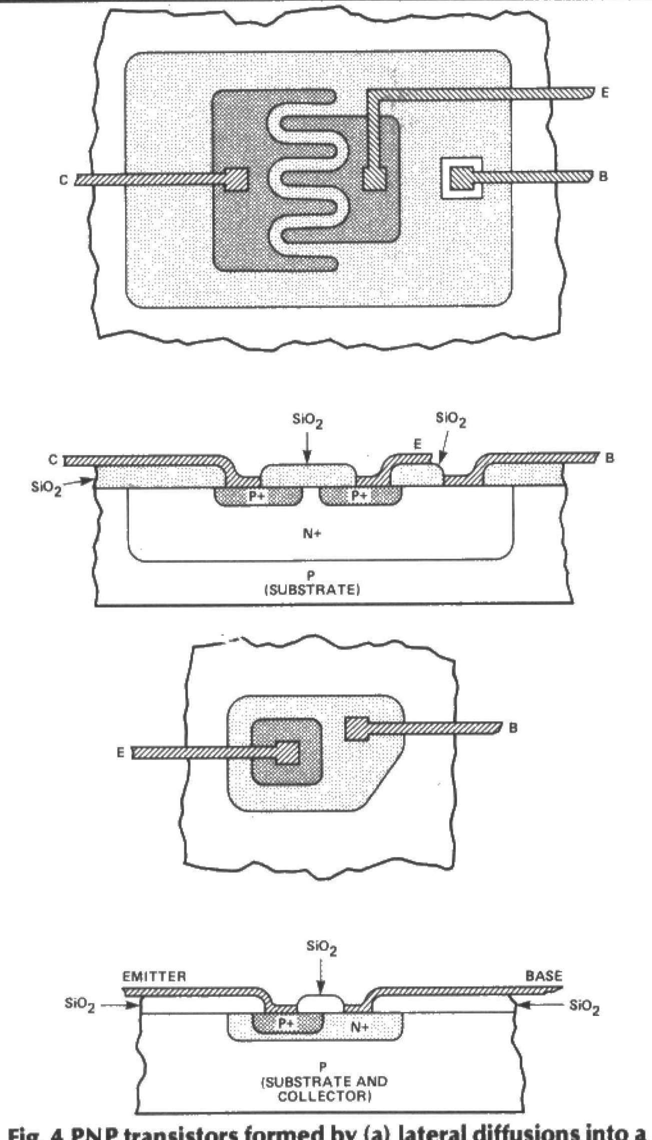


Fig. 4 PNP transistors formed by (a) lateral diffusions into a P-type substrate and (b) successive vertical diffusions into a P-type substrate.

of the form shown in Fig. 5, with a couple of input connections (one inverting and one non-inverting), an output pin, and a couple of leads for a dual rail supply. The supply voltage can lie anywhere between ±1.5V and ±18V depending on the op-amp specification.

The basic circuit layout employed is of the form shown in Fig.6. The input transistors, Q1 and Q2, are connected as a long-tailed pair, Q5 is an amplifier stage, and Q6 and Q7 are a push-pull output stage biased into class

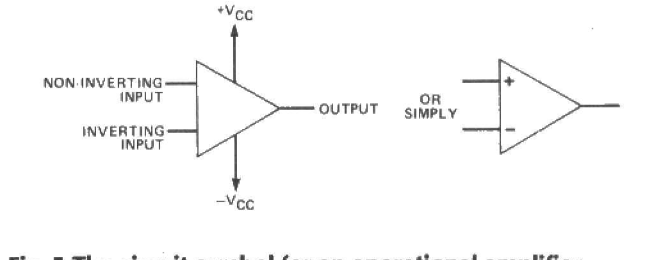


Fig. 5 The circuit symbol for an operational amplifier.

AB. In modern designs there will also be an internal HF compensation capacitor, which I have shown as Cc.

Although there has been a proliferation of op-amp types in the past decade, they all have certain features in common. These are an open loop gain (that is, the gain without externally applied negative feedback) in the range of 50,000–250,00, a low static power supply consumption, usually in the range 0.5–4mA, a high common-mode rejection ratio (by which is meant the ability of the op-amp to ignore signals which are present simultaneously on both inputs while amplifying the difference between such signals) and a high degree of rejection of any voltage variations on the supply lines.

This latter feature allows the circuit designer to ignore the need for supply line decoupling in a way

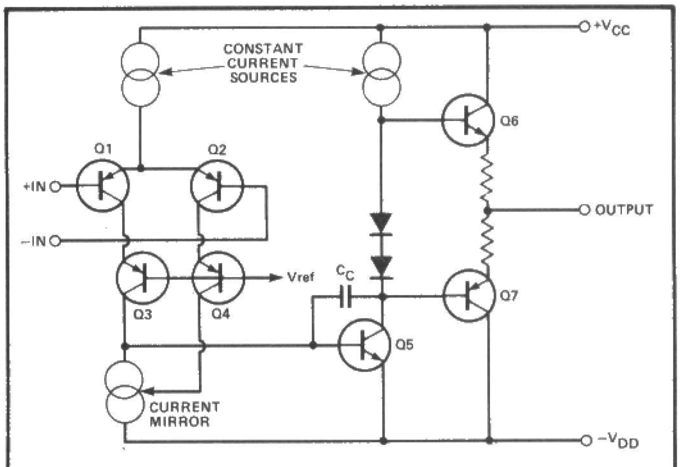


Fig. 6 Simplified internal circuitry of a basic operational amplifier.

which would have been disastrous for the valve circuit designer, and for which I, for one, am truly thankful.

Early general purpose op-amps were uncompensated. This meant that one had to be careful when applying negative feedback between the output and the inverting input, unless two external HF compensation networks of suitable values of R and C were connected between four of the pins.

At the time, this was a necessary requirement if a respectable HF bandwith for the amplifier was to be achieved, but it was an inconvenience which one could

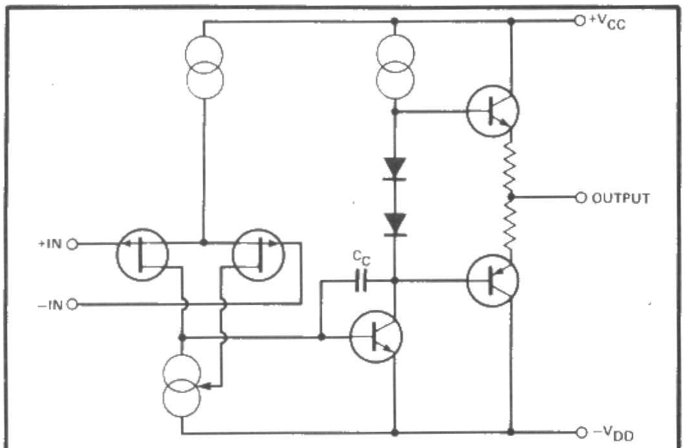


Fig. 7 Simplified internal circuitry of a Bi-FET operational amplifier.

well do without. Subsequent 'second generation' op amps like the familiar 741 had the worst-case HF compensation components built in, without too much sacrifice in performance.

A later development was to make dual and quadruple op amps in the same package. The dual ones, in an 8-pin DIL or TO5 pack, have become very popular.

Drawbacks

Early op-amps, while they did what they were supposed to, had a lot of snags, which were seldom mentioned in the makers' catalogue descriptions.

Noise This was partly due to the fact that the whole of the electronic circuitry floated on top of a P-type silicon slice and was isolated from it by reverse biased diode junctions. As I mentioned in an earlier article, the leakage currents in reverse biased diodes are very noisy. Also, the transistors used were heavily and multiply loaded with impurities, which certainly didn't do their noise figures much good.

Output overload Again, in early types, no specific form of output overload protection was employed, so if the output became short-circuited the op-amp would burn out.

Latch-up If the output was driven hard in one direction or the other, it often just stayed there, regardless of what the signal at the input subsequently did.

Input protection No specific protection was included to prevent damage to the device if the input was taken, quite legitimately within the supply voltage range of the IC, to an ill-chosen voltage level.

Frequency response This was often quite poor when any significant output load was applied or if a wide output voltage swing was required. The slewing rate could also be poor and often differed for positive-going and negative-going output swings

Input impedance This could be quite low, and the input bias currents (those currents which must flow into the IC if it is to work) were often relatively high.

Third Generation Op-Amps

Most of these problems were removed in the second generation designs, such as the 741, but the problem of a relatively low input impedance remained, with a consequent need for a carefully matched resistance path in both the inverting and non-inverting input circuits. The HF bandwidth and noise figure were also not nearly as good as could be achieved with discrete components.

Careful attention to the doping of the various regions of the IC, and in the choice of dopants employed and the way in which they are introduced, has led to great improvements in the noise figure of a modern IC op-amps. Improvements in circuit design have also helped.

However, the major breakthrough came when techniques were evolved for producing FETs on the same chip as bipolar transistors. This allowed the construction of Bi-FET types of op-amp such as the Texas TL071 and the National Semiconductors LF351, which have a remarkably good performance.

These have the general circuit layout shown, in slightly simplified form, in Fig. 7. This is very similar to the 741, whose structure I illustrated in Fig. 6, except that the cascode-connected PNP input transistors (used to compensate for the poor performance of the lateral PNP types), have been replaced with P-channel junction FETs.

This gives a noise performance which is very nearly as good as that obtainable from the best of the discrete component circuit layouts, an output voltage swing very nearly equal to the difference between the +ve and −ve supply rails over the whole audio bandwidth, and a harmonic distortion, on loads of 4k7 or greater, which is

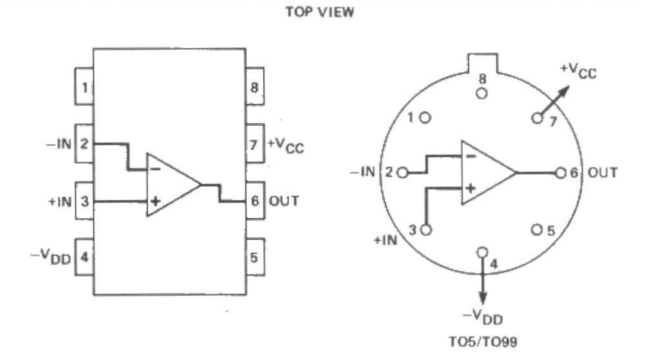


Fig. 8 Pin connections for 8-pin DIL and T05/T099 packaged single op-amps such as the 741, TL071, LF351, NE5534, etc.

typically well below 0.01% for a stage gain of 20x or less. In addition the input impedance is of the order of a million megohms, which means that one doesn't have to worry about the input circuit resistance values being precisely matched.

The pin connections used for the single op-amp designs are shown in Fig. 8.

A feature most modern IC op-amp designs possess is an offset-null facility, to allow the output DC voltage to be set precisely to zero volts plus or minus a few millivolts. This is commonly done by connecting a small trimmer potentiometer between pins 1 and 5 and taking the slider to the -ve supply rail, as shown in Fig. 9. It is wise to check the recommended connections and circuit values if the op-amp used is not a 741, LF351 or TL071 since some types differ in their requirements.

Nulling the DC output voltage (only practicable if the input voltages are near zero) is only necessary if the amplifier is being used in a DC application, such as a DC energised strain-gauge or thermocouple amplifier.

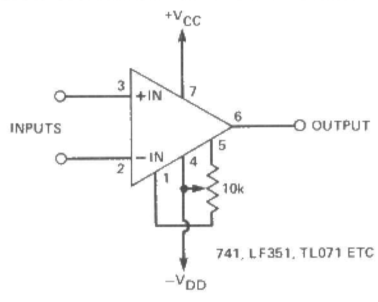
Since this isn't a very common application, the quite popular dual ICs such as the bipolar MC or LM 1458 or the LF353/TL072 BiFET types omit this connection. Their pin connection arrangements are shown in Fig. 10. With both inputs connected to the 0V line and a gain of up to 100x, a DC offset of less than 100mV would be expected even without any HF DC nulling.

The type of circuit used with an op-amp as a general purpose AC amplifier stage is shown in Figs. 11a and 11b.

The non-inverting stage has a higher input impedance Rin, which can be as high as one likes, but a slightly worse distortion figure and an inferior sound in audio applications when compared with the phase-inverting circuit of Fig. 11b, in which the input impedance is equal to Ra.

This difference is due to a slight failure in the op-amp common mode characteristics. It is only worth worrying about this in 'ultimate Fi' audio applications. For all normal purposes there is no measurable difference between the two.

Fig. 9 Offset-null arrangement in which a potentiometer is used to set the DC output voltage accurately at zero volts.



The third common configuration in both AC and DC usage is the unity-gain impedance converter layout of Fig. 11c. This will convert an input signal at the megohms level to a very nearly identical signal at an output impedance of less than 1k0.

In all of these applications, where negative feedback is being used to define the gain or improve the performance of the op-amp, it is prudent to include an output resistance of the order of 100-220R. This will reduce the likelihood of the amplifier becoming unstable should the output load have a particularly unfavourable reactance characteristic. If the circuit is driving something whose input impedance is purely resistive, this can be omitted.

The circuit applications in which op-amps can be used would fill a book — indeed they have already filled several books — so this is not the place to compete with this outpouring of ingenuity. The thing to remember is that the more recent designs are, inevitably, better than the earlier ones, partly as a result of competition between manufacturers and partly because new design techniques are continually being discovered which lead to better products.

Also, one should remember that there are, as the old saying has it, horses for courses. If one wants a very high input impedance indeed, for use, perhaps with an ionisation chamber, but low noise and low distortion are not terribly important, then a MOSFET input op-amp like the RCA CA3140 or the more recent Intersil ICL 7611 DCPA, would be the best choice.

If on the other hand, very low noise indeed is required, perhaps for some audio application, but a high input impedance isn't particularly important, then the Signetics NE5534 or its dual package equivalent, the NE5532 would be a good choice. If cost is of no consideration whatever, a Precision Monolithics OP-27, currently the Rolls-Royce of bipolar op-amps, would make an enviable possession, particularly since it combines very low circuit noise with a very low DC drift and equally low distortion characteristics.

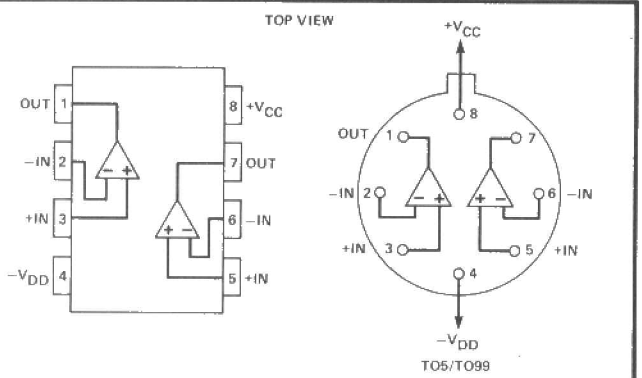


Fig. 10 Pin connections for 8-pin DIL and T05/T099 packed dual op-amps such as the MC1458, TL072, LF353, NE5532, etc.

Other Op-Amp Types

Additional possibilities which exist in the op-amp field are devices like the TL061 (062 dual, 064 quad) series, which, in addition to a FET input, have a typical current consumption of 0.25mA per amplifier and are ideal where economy in use of supply current is desirable. Even more frugal is the OP-220 device with a consumption of 100uA, or the OP-420 quad op-amp which lives on a beggarly 50uA per amplifier.

Alternatively, ICs like the TL091 (092 dual) offer the facility of operation from a single line supply, provided that the input and output voltage swings are not required to go outside the supply voltage range.

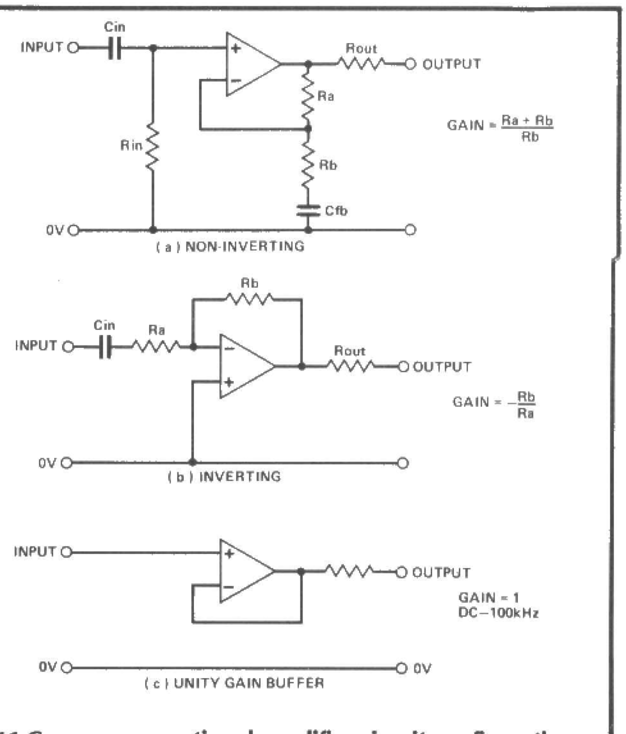


Fig. 11 Common operational amplifier circuit configurations.

Where DC amplification for strain gauges or similar low output transducers is required, the National Semiconductor LM725 or the Precision Monolithics OP-07, OP-27 or OP-37 devices would be preferable.

There are also IC op-amps aimed at very fast response, wide-bandwidth applications, such as the National Semiconductors LH0024 and LH0032 designs which have a 70MHz bandwidth, and the LH0063/HA5033 unity gain buffer ICs, which have a DC-100MHz pass-band. However, it should be remembered that such devices will require a lot of care in the layout design if stable operation is to be obtained.

If more muscle power is required there are also power op-amps, though a simple and relatively low-cost

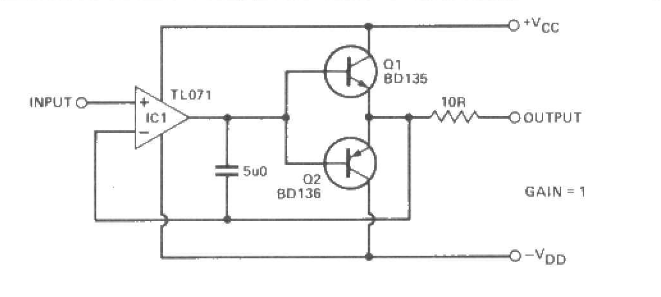


Fig. 12 Using a pair of transistors to increase the output power of an op-amp.

alternative is to hang a pair of transistors on the output of a conventional op-amp as I have shown in Fig. 12. Since the output transistors are zero biased they take very little quiescent current, but the residual crossover distortion would spoil the performance for audio use. If low THD is needed, the transistors must be biased into class A or class AB as shown in Fig. 13. This produces a very good headphone amplifier design.

Interpreting The Specifications

Most of these are fairly simple to understand, but there are some IC parameters which are a bit confusing. Input Offset Voltage refers to the difference in the base-emitter voltages between Q1 and Q2 in Fig. 6. This

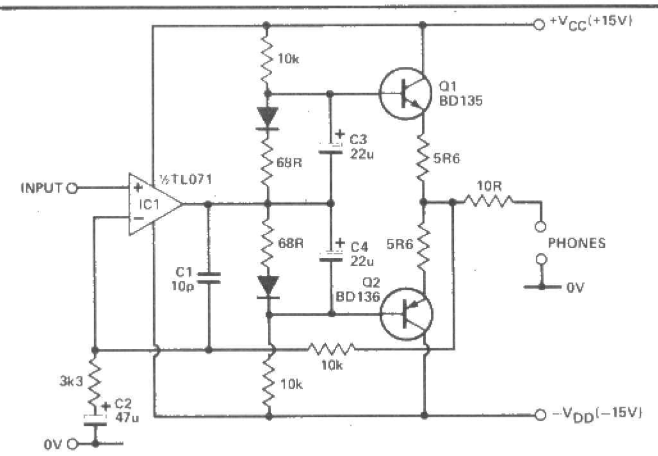


Fig. 13. An alternative method of boosting op-amp output power which introduces less distortion.

would give rise to a spurious apparent DC input signal, to be amplified by the op-amp voltage gain. Typical offset voltages for a 741 type op-amp would be in the range 2-5mV, in the absence of an offset trim adjustment. FET input op-amps would be worse than this were it not for the fact that they are usually laser trimmed to around the 2mV level.

Input Offset Current refers to the difference in the base currents of Q1 and Q2 in Fig. 6. It is usually a good bit less (5-10x) than the input bias currents, which are the actual base currents drawn by the input transistors. It will cause an unwanted voltage offset if the resistance of the two input circuit paths are unequal.

The input bias and offset currents in FET input op-amps are usually too low to be of great importance in normal circuitry.

All of these offset voltages will probably be worse at temperatures higher or lower than the 25°C figure normally specified for commercial grade ICs. Military or industrial specification units will be better in this respect.

Input offset voltage drift is specified as a function of temperature and relates to the temperature stability of the circuit. It is influenced by care in matching the input transistor chip areas and doping levels, and is a parameter which is unlikely to be specified except in relation to Military op-amps or those which are intended for use in DC instrumentation applications.

Voltage Regulator ICs

The second class of linear ICs which I feel one should not try to do without is the three-terminal voltage regulator IC. This is an invaluable aid in ensuring that circuits work as well as one would hope by providing a

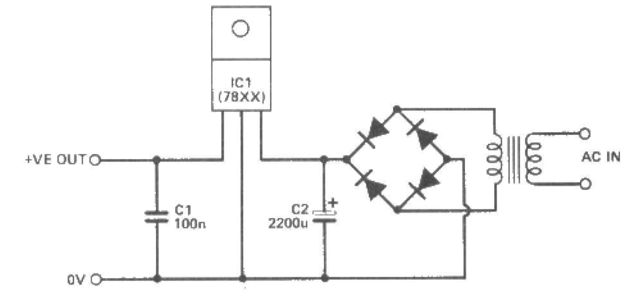


Fig. 14 A three terminal voltage regulator in a standard positive supply line regulator arrangement.

stable, precisely controlled, low ripple, low impedance and low noise DC supply line.

The type of circuit layout used is shown in Fig. 14 and the simplified internal circuitry is shown in Fig. 15. The only thing which it is necessary to remember in use is that the negative supply line regulators (usually listed as the 79 series) have a different pin configuration to the positive line (78 series) ones. The pin connections for a number of different packages are shown in Fig. 16.

In addition to the fixed output voltage types (7805, 7812, 7815, 7824 etc.) there are adjustable output voltage versions. These are good, but not quite as good in performance as their fixed voltage brothers.

At present, there is a general limitation of 40V as the maximum input voltage which may be applied. Higher

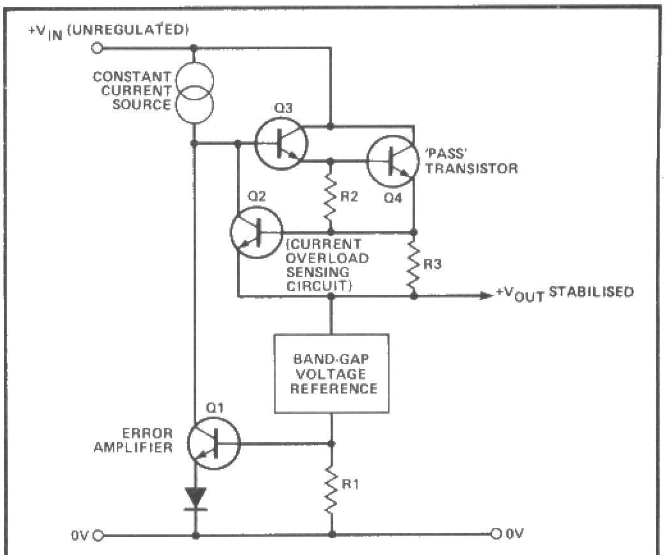


Fig. 15 Simplified internal circuitry of a positive supply line three terminal voltage regulator.

voltage types are beginning to appear but at present they are very costly.

Unlike zener diodes, the three-terminal IC voltage regulators employ a relatively nose-free band-gap type of voltage reference which is compensated for temperature variations. They are amplified to give higher voltages than the 1.205V silicon band-gap potential (the voltage which a forward conducting diode would have at absolute zero temperature), and so are preferable as sources of stable DC potential. However, at least 5% of the rated output current must be drawn from the device if a good performance is to be achieved.

Typical output impedances for such a voltage regulator IC can be well below 0.1 ohms down to as low as 1 Hz. It would require a decoupling capacitor of 1.5 farads to equal this! To ensure proper operation, the output capacitor, C1 in Fig. 14, should be at least 100n. More than 10u is unnecessary.

These ICs also contain internal circuit elements to provide protection against inadvertent output short-circuit or thermal overload due to a combination of excessive current and input-output voltage drop.

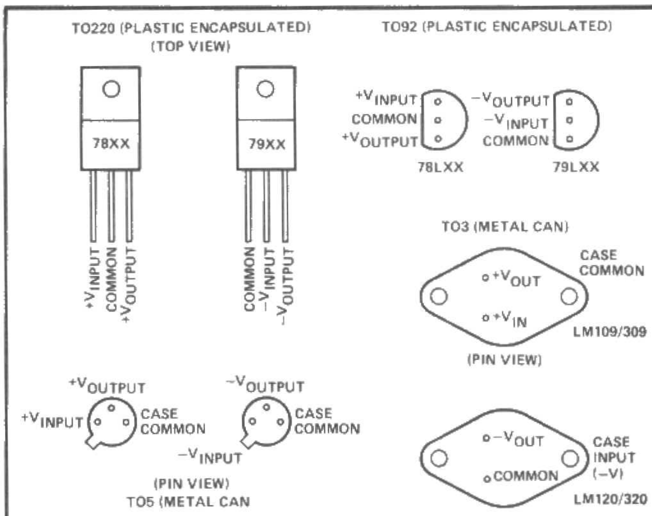


Fig. 16 Pin connections for the most popular types of three terminal voltage regulators.

Other Linear ICs

There are an enormous number of other linear ICs, and every month new ones appear. These are mainly aimed at special fields of application, such as TV sets, FM tuners, various industrial and automotive applications and audio circuitry. The competition in the TV and audio field is largely for low cost units for the relatively undiscriminating user, and the more of the circuitry which can be done with ICs, the lower the price tag will be.

It is a fascinating field to explore, but I always remember the dozens of special purpose ICs which I have seen in the past and which are now no longer made. I try to stick with the rather longer lived general purpose designs, of which the op-amps and the voltage regulators seem to be the most useful.

Next month I will look at the strengths and weaknesses of the various types of digital ICs, such as standard TTL, ECL, Schottky, LS, ALS, CMOS and HCMOS.

ETI

FROM A TO D AND BACK AGAIN

Data converters are finding their way into an ever increasing range of electronic equipment, including a number of ETI designs. Stuart Smith takes a closer look at some of the more common types.

Nowadays, digital circuitry is very often used to process signals which originate in analogue form. The results of the processing may need to be reconverted into analogue form, and different conversion methods have been developed to meet the needs of different applications. These vary from the high speed/low precision requirements of a video digitiser to the slow speed/high precision of a digital voltmeter.

Back To Front

Digital to analogue converters (DACs) are the simplest and I'll describe them first.

Usually the ouput of a digital circuit is in the form of a set of words of fixed bit-length. Occasionally it takes the form of a frequency. A frequency-to-voltage converter will serve for the latter kind of output and the general principle is shown in Fig. 1.

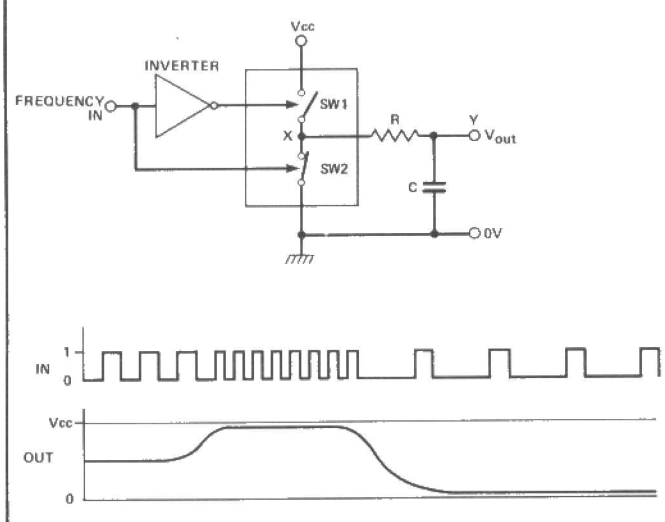


Fig. 1 Structure of simple frequency-to-voltage converter.

The node X is switched to either Vcc or 0V at a rate dependent on the input frequency. As long as the input pulses are of fixed width (which can be arranged using edge-triggered monostables) the mean output voltage at Y is proportional to the input repetition frequency. If CMOS bilateral switches, such as the DG200 or 4066 types, are used for S1 and S2 their own ON resistance can provide the R component. The maximum input frequency is limited by the switching speeds of S1 and S2 and the minimum frequency by the value of C. If C is too high, the output will take a long time to respond to changes in frequency. If C is too small, the output will ripple as each input pulse arrives.

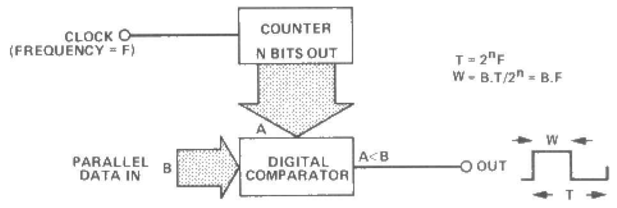


Fig. 2 Parallel input decoding giving an output whose pulse width is proportional to input.

Most digital circuits do not produce variable-frequency outputs — they give parallel digital data. To decode such inputs, the circuit of Fig. 1 can be effectively extended as in Fig. 2, although it is rather too slow for some applications. Instead of a variable rate, fixed width input, the technique uses variable width pulses at a fixed rate.

For higher speeds, the method of switching weighted resistors (Fig. 3) can be used. The illustration shows an 8-bit DAC with the weighted resistors so numbered that $Rx = R.2^{8-x+1}$. In general, an n-bit DAC can be constructed with $Rx = R.2^{n-x+1}$. In such an op-amp configuration, the inverting input is a virtual earth point and the current flowing in one of the resistors when it is switched in is Vref/Rx. The output voltage due to that current will be -Vref.(R/Rx) which simplifies to -Vref.(R/$(R.2^{8-x+1})$) or $-Vref/2^{8-x+1}$. For any particular input number, several resistors will be switched in and the output

FIG 5 BELOW OOPS! ERROR/CORRECTION FROM ETI SEPTEMBER 1985 P.52

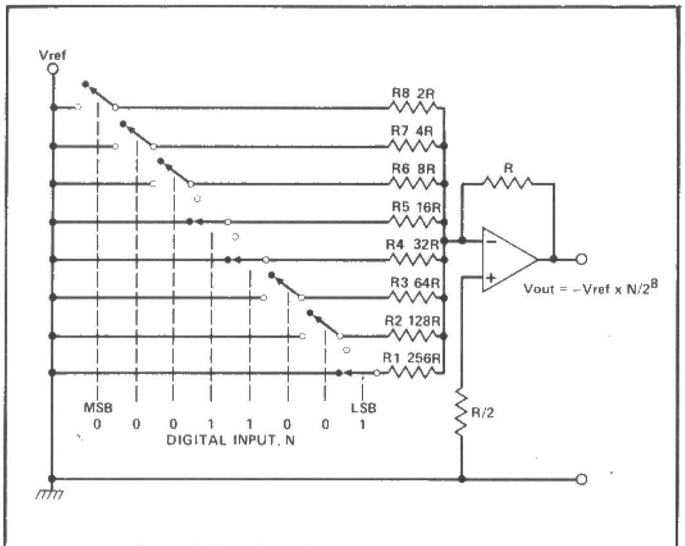


Fig. 3 Basic weighted resistor D-to-A.

will be summed. For example, if the input is binary 11001 (decimal 25), the output will be Vref.(1/256 + 1/32 + 1/16) or Vref.(25/256). A little calculation will show that the output of our 8-bit DAC will be Vref.(A/256), where A is the number input in binary form. For an n-bit DAC, the output will be Vref.($A/2^n$).

In a practical circuit, the switches S1-S8 would have finite resistance and so the correct weighting of each input would be difficult to achieve. Apart from this problem, the type of converter shown in Fig. 3 requires a very large range of resistance values for even a modest ten bits. As the number of bits increase, the resistor tolerance constraints become tighter. Take the example of an input code change from 0111 . . . to 1000. . . . If the MSB resistor is one part in 2^{10} out then the analogue out-

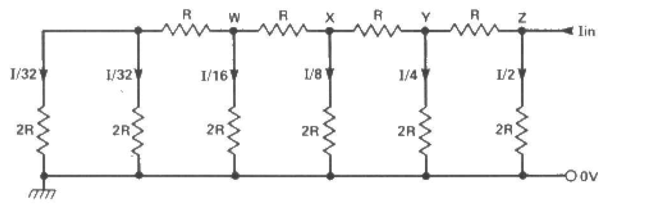


Fig. 4 An R-2R ladder of the type used in many DACs.

put of a ten-bit DAC may actually decrease on this major carry. In fact, accuracy should be to within a half of the LSB weighing or, in the case of a ten-bit DAC, to 0.05%.

Divide And Rule

Tolerances of this precision and beyond are difficult to maintain over a wide range of resistances and temperatures. It would, then, be useful to have a circuit which did not require such a large range of resistor values.

Such a circuit is the R-2R ladder network, a series of potential dividers which forms the basis of many DACs in use today (Fig. 4). It is widely used as part of the reference DAC in successive-approximation ADCs (see later).

At each node (W, X, Y, Z) current entering from the right 'sees' a resistance of 2R to the left and 2R downwards, so it divides equally down each arm. Thus binary weighting of currents is achieved in each vertical arm, and consequently, a binary weighting of voltages across the 2R resistors. By suitable adjustment of the resistors, a logarithmic weighting can be achieved.

The R-2R ladder is very often used in the configuration of Fig. 5, which shows a 5-bit DAC. The reference voltage, Vref, is converted to a current Iref = Vref/Rin, flowing in the reference transistor Q1. The currents flowing in the other transistors can be switched to either the output or ground, depending on the setting of the bit switches. The switch resistance is unimportant because of the use of constant current sources T2 to T6.

In some commercial DACs the individual outputs may be switched to a true or complement current output; the sum of these two output currents is always equal.

The output of any DAC is proportional to the product of the voltage reference and input code. Some converters are designed so that the voltage reference may

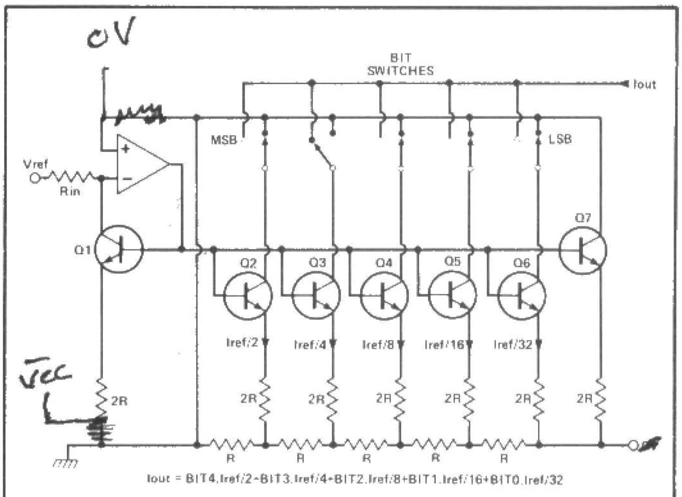
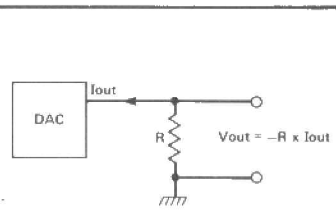


Fig. 5 A five-bit DAC using the R-2R ladder.

vary widely during operation — these types are designated 'multiplying' converters. A high quality multiplying DAC may be used as a digitally controlled attenuator in an audio system; the Analogue Devices AD7110 is an example of a DAC specifically tailored for this application — it attenuates input signals in 1.5dB steps according to input code.

Fig. 6 Voltage from a current output DAC.



The output signal is often wanted as a voltage, rather than a current. Of course, this can be achieved with a resistor, but the output voltage will always be negative (Fig. 6). Also the output voltage swing is limited by the 'compliance' of the DAC outputs, which is the range of output voltages over which constant output current will be delivered. Some are not capable of maintaining constant output current unless the output voltage stays close

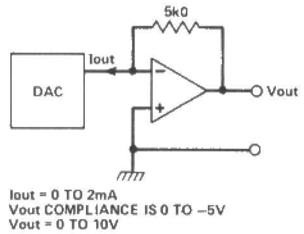


Fig. 7 Using an op-amp to get a buffered, positive voltage from a current output DAC.

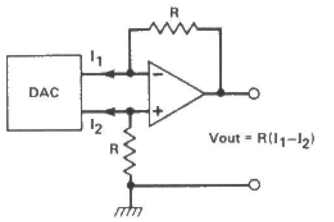


Fig. 8 Using an op-amp to give a buffered, bipolar voltage from a current output DAC.

to zero. Finally, the output voltage will change if it is loaded by another resistance.

It is, then, quite usual to add an op-amp to provide gain, buffering and the correct polarity of output voltage. Some proprietary DACs incorporate an output op-amp to provide voltage output. Figures 7 and 8 show two methods of connecting a current-output DAC as a voltage-output device.

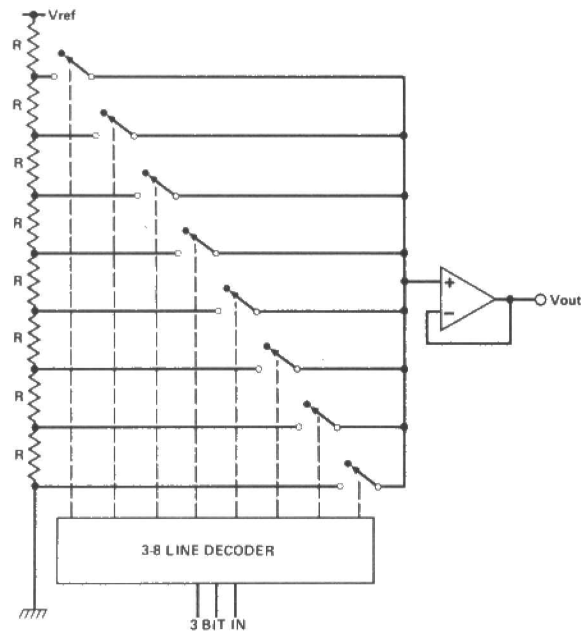


Fig. 9 Direct decoded resistor ladder DAC.

Another DAC structure in common use incorporates a ladder of equal-value resistors — 2^n of them for an n-bit converter. The reference voltage is applied across the ladder and a fixed fraction of it is tapped off by a series of switches. (Fig. 9).

This structure is unwieldy for many bits — at eight bits, an eight-line to 256-line decoder with 256 control lines is required. An alternative arrangement uses more switches but incorporates decoding in the wiring and

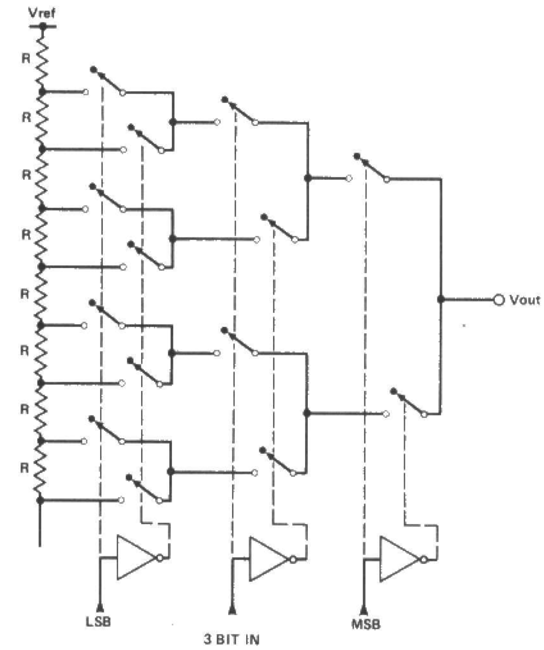


Fig. 10 Tree decoded resistor ladder DAC.

requires only 2.n control lines (Fig. 10). This method is known as tree decoding, and, since voltages are being switched, is probably best suited to MOS implementation, because MOS switches introduce no offset voltage.

Flash, Bang, Wallop . . .

The analogue-to-digital converter is a rather more complicated device than the DAC. ADCs often incorporate a DAC as a feedback element, to improve the performance of the ADC.

The most direct implementation of the A to D function is probably the parallel or 'flash' converter, so called

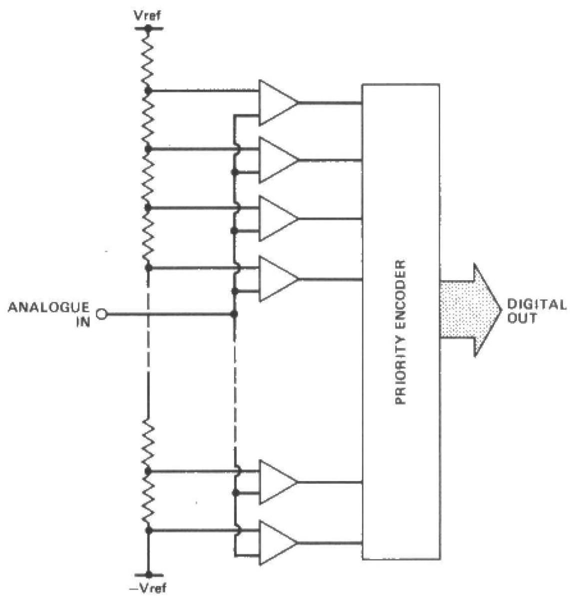


Fig. 11 Flash analogue-to-digital conversion.

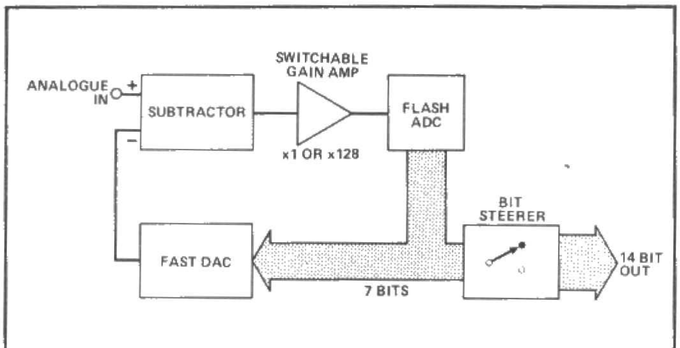


Fig. 12 Two-stage flash ADC.

because of its speed (up to 100 million conversions/sec) (Fig. 11).

A voltage reference is divided by an equal value resistor string into 2^n equal steps for n-bit conversion. These voltages are applied to the reference inputs of 2^ncomparators. The input voltage is applied to all the comparators simultaneously. A priority encoder gives an n-bit digital output indicating where the comparator outputs change from low to high.

The flash converter is rather expensive — for ten bits no less than 1024 resistors and comparators are required, as well as a correspondingly large logic circuit to encode the output. An interesting variation on the flash converter, which sacrifices only a little of its speed whilst considerably reducing the complexity, is the two-stage converter, an example of which appears in Fig. 12.

During stage I, the analogue input is decoded with seven bit precision. A fast, accurate seven-bit DAC returns a value equivalent to the ADC output. The ADC output is stered to the most significant bits of the output register. The DAC output is stored for use in stage II. In stage II, the previous DAC output is subtracted from the analogue input, leaving a remainder which is some fraction of the converter's most significant bit. This fraction is amplified by 128 ($=2^7$) and converted by the flash converter to provide the seven least significant bits.

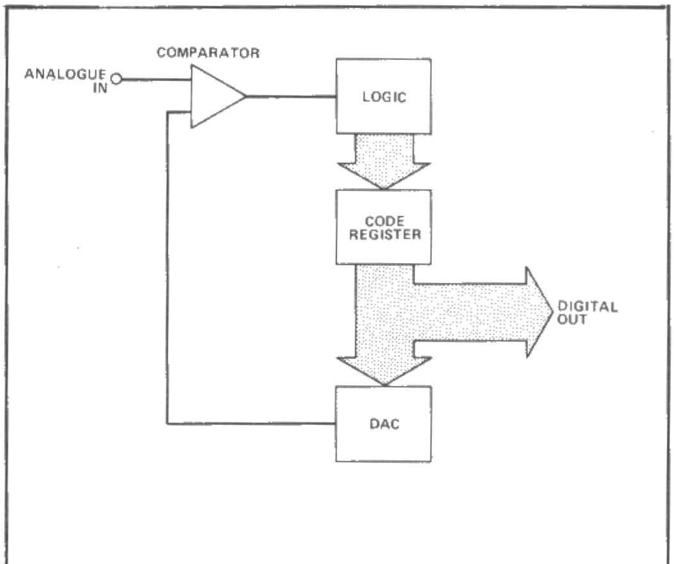


Fig. 13 Successive approximation ADC - block diagram.

Successful Approximation

Another important ADC method is successive approximation, which is of medium to high speed (up to 50,000 10-bit conversions/sec). Successive approximation is probably the most popular ADC method today.

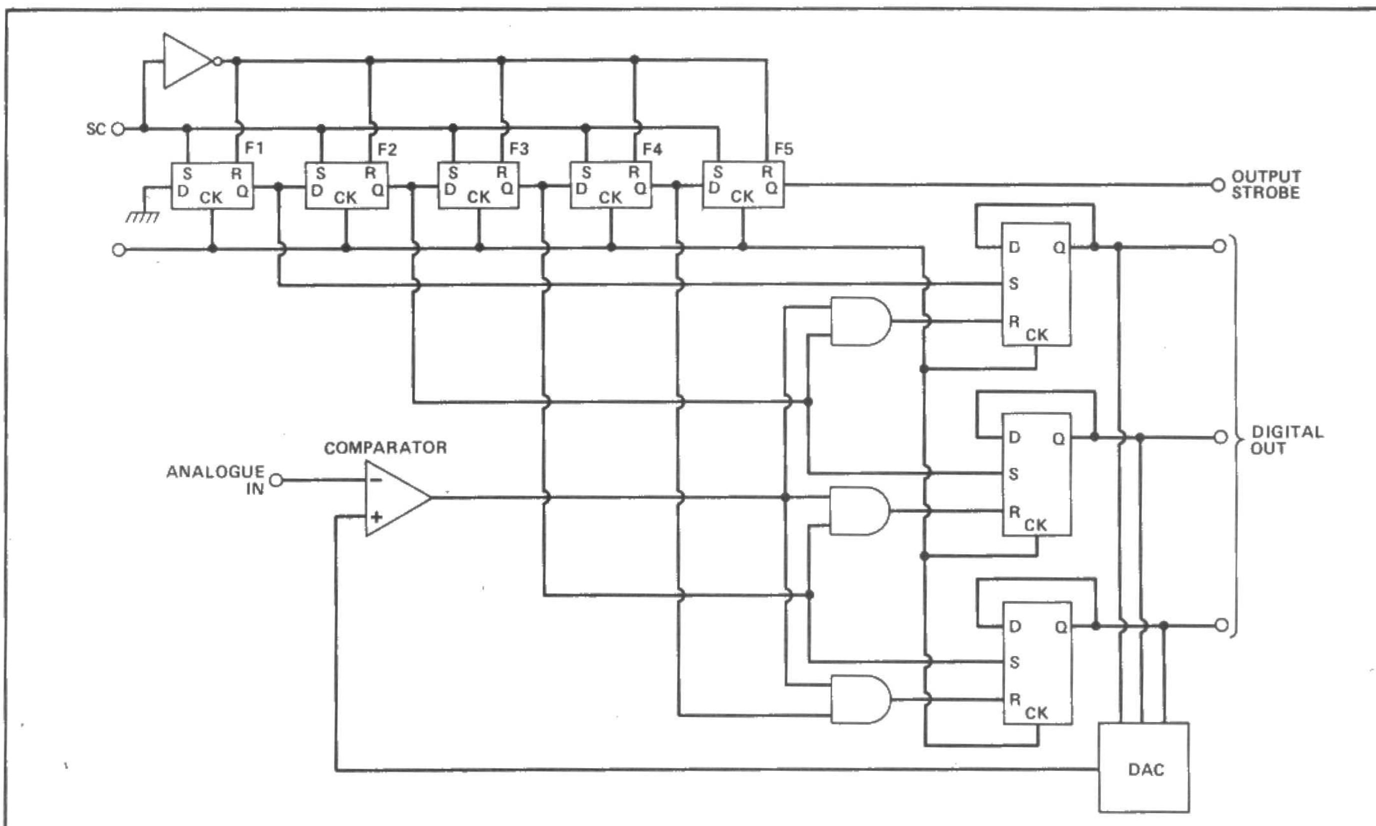


Fig. 14 Three-bit successive approximation ADC.

A block diagram of a successive approximation converter is shown in Fig. 13. A register is filled with ones in one bit position at a time. The register output is applied to a DAC and the resulting analogue output compared with the ADC input. On the basis of this comparison a decision is made on whether to retain the bit just tested or discard it. The total conversion time is approximately n times the DAC setting time.

The basic hardware implementation of a sucessive-approximation (SA) register, using S-R flip-flops, is shown in Fig. 14. The top line of flip-flops is the sequencer, which puts a one in successive code register flip-flops, MSB first. The bottom line of flip-flops is the code register,

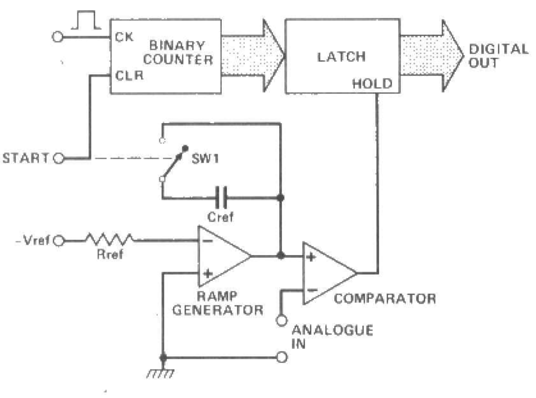


Fig. 15 Ramp comparison ADC.

which holds estimates of the digital code representing the input signal.

On receipt of a START CONVERT pulse, the sequencer is set to 1000, which sets the code register to 100. This code is applied to a DAC, and the resultant output is compared with the analogue input. If the estimated code is too high, the comparator output goes high. When a CLOCK pulse arrives, the sequencer output goes to 0100 and the R input of F2 will be 1, so the code register's MSB is reset to 0, and the new code is 010. At the next CK pulse F1 may be Reset, depending on the comparator state. This process repeats until all the bits have been tested.

During the SA process the analogue input must obviously remain constant. It is usual to sample and hold the input signal before applying it to the ADC.

If a high conversion speed is not required, a microprocessor (or microcomputer) can take the place of the

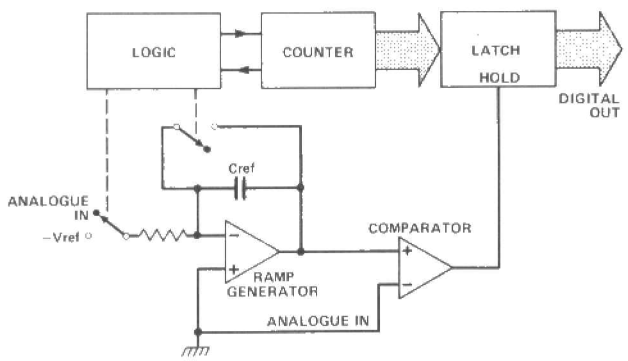


Fig. 16 Dual ramp comparison ADC.

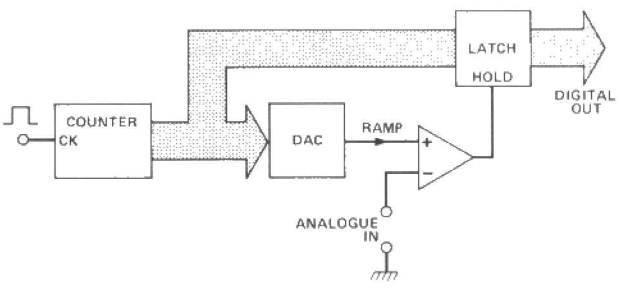


Fig. 17 Using a DAC to generate a ramp voltage.

SA hardware. The program is very simple, and may allow a high precision, low-speed ADC to be built using just a comparator and precision DAC in addition to the processor.

Ramp Until Ready

In the ramp method (Fig. 15), a ramp voltage is generated by an integrator, synchronised with a clock. The clock is applied to a counter, which is stopped when the ramp voltage equals the input voltage. At this time the counter output is a binary number proportional to the input voltage.

The dual slope integrating converter (Fig. 16) is an extension of this idea, and is a popular circuit in digital voltmeters. The integrating capacitor is charged first of all for a fixed time by a current -Vref/Rref, and then

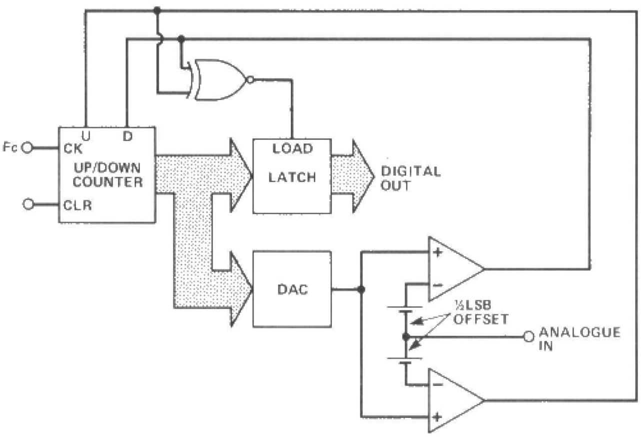


Fig. 18 Tracking ADC - block diagram.

discharged by the unknown current, Vin/Rref, until the integrator output reaches zero. A counter times this discharge period and the number it reaches is proportional to the analogue input.

In this way the Rref and Cref need not be precision components, and the comparator specifications can be relaxed as it has only to compare with a ground reference. It is also possible to null out offsets before every conversion by introducing a third stage during which 0V is integrated and the resultant output stored.

Both these types of single and dual slope converters suffer from having to generate ramps by analogue means which are synchronised to digital circuitry. Another method uses a DAC on the counter output to generate a ramp voltage which is compared with the input voltage

(Fig. 17). When the comparator changes state, the clock is stopped. The conversion time of this type of ADC varies with word length and input voltage. It takes less time to ramp up to a small input, and if fewer bits are used, fewer clock cycles are required to reach a given fraction of full scale.

A more elaborate scheme uses two comparators and an up/down counter. This is the tracking type of converter (Fig. 18). The maximum conversion rate depends on the rate of change of the input signal, not it's absolute value. To prevent the output jittering about a code, the ½ LSB offsets shown are introduced to the comparators. If the input is within this LSB wide window the counter is held.

A final type of circuit is the non-linear converter, which operates by assigning more codes to low input voltages, giving a higher resolution. An example of a coding law for a three-bit non-linear device is shown in Fig. 19.

Some types of signal — for instance, speech — show predominantly low levels. An eight-bit non-linear converter might have effective 12-bit resolution for signals from 0 to 25% of full scale, and only four bits for signals from 75 to 100% of full scale. But if the signal spends 80% of it's time between 0 and 25% of full scale, the effective signal-to-noise ratio is similar to that obtained from a 12-bit converter, but with only eight-bit complexity. These types of converters are used in telecommunications to reduce transmission bit-rates and hence bandwidth.

An example of this type of converter is the Precision Monolithics PMI DAC78, which uses the three most significant bits to select one of eight 'chords' of output — shorter for lower input codes — and the next four bits to select one of 16 levels within each chord.

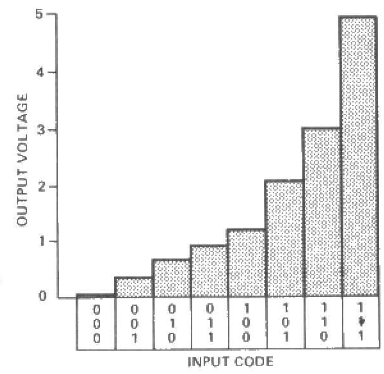


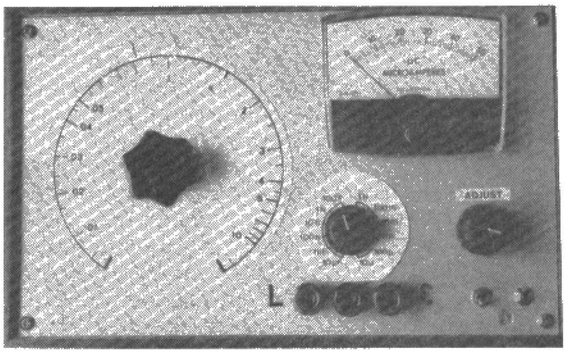
Fig. 19 An example of non-linear coding weighting low-value inputs.

Data converters are now available in many guises to make their implementation easier, multiple converters in one package, time-multiplexed converters in one package, devices with serial digital inputs or outputs, and some which accept BCD rather than straight binary inputs. Special devices, designed to be easy to interface to a microprocessor, are also on the market.

This variety, combined with the falling cost of complex digital hardware, leads the way to a future where data converters are almost as commonplace as the op-amp.

ETI

RCL BRIDGE



With precision autoranging digital meters available to test just about every electrical quantity, the humble measuring bridge has been rather neglected of late. L. Boullart feels it's time we took another look.

Is there still a need for a measuring bridge? As far as resistors are concerned a digital or FET multimeter will do the job just as well. We all know that digital capacitance meters can be very accurate pieces of gear, but they are quite expensive and I suspect that many hobbyists don't have one. On the other hand, a measuring bridge — even a modern high-quality one — is reasonably cheap, and it is quite possible to obtain an accuracy of 1% or even better with a good design.

But doesn't it take longer to carry out a measurement? Not really: I have never worked on a new design without it. Perhaps I am over-cautious, but I always test the capacitors, the resistors and the inductors before soldering them to the printed circuit board. If the design doesn't work properly from the start, at least I know it is not the Rs, Cs and Ls!

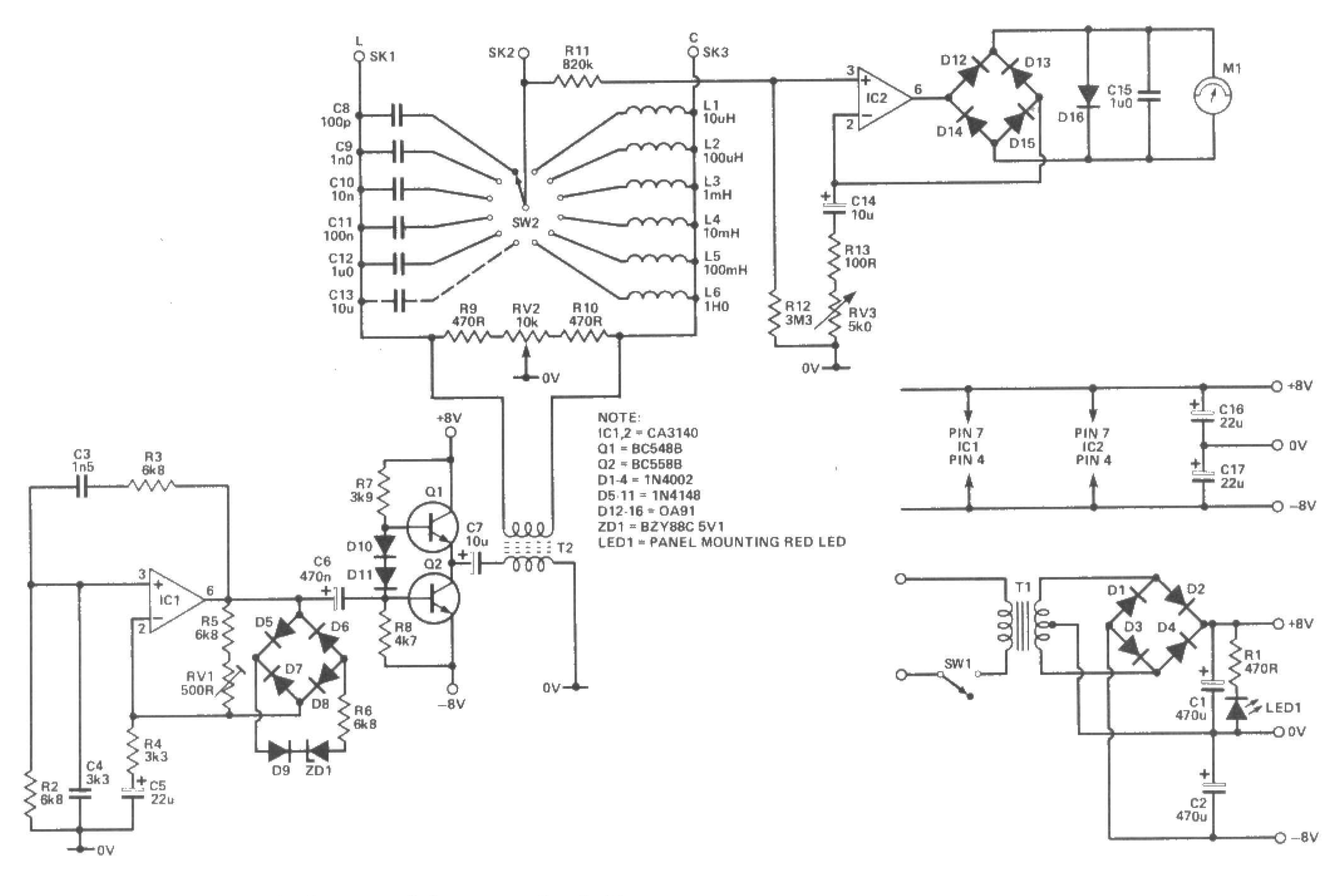


Fig. 1 The complete circuit diagram of the measuring bridge.

A measuring bridge consists of three parts:

1) a generator which feeds an AC voltage to the bridge
2) the bridge proper with switchable elements (capacitors, inductors, resistors)
3) a measuring amplifier to indicate the tuning of the bridge.

The Generator

In older bridges the generator often used the 50 Hz signal from the mains, injected into the circuit by means of a suitable transformer. However, such a low frequency will seriously limit the range of capacitors and inductors that can be measured.

Consider, for example, the impedance of a 10 uH inductor at 50Hz:

$$Z = 2\pi fL$$
$$= 6.28 \times 0.05 \times 0.01$$
$$= 0.00314 \text{ ohms}$$

which means a virtual short circuit.

On the other hand, a capacitor of 10p will have an impedance:

$$Z = \frac{1}{2\pi fC}$$

$$Z = \frac{10^3}{6.28 \times 0.05 \times 10 \times 10^{-6}}$$

$$= 318 \times 10^6 \Omega$$

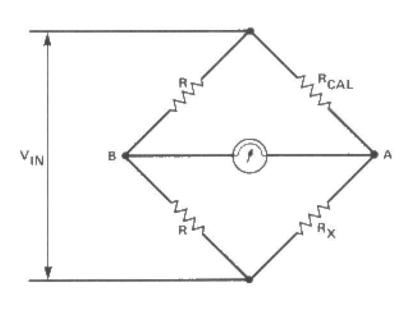


Fig. 2 A basic measuring bridge.

Clearly, we will have to look for a compromise.

First, let us assume a scale with a range from 0.1 to 10 times the central value, a sensible compromise of range and accuracy of reading. Next, what are the smallest and the largest values of C and L we wish to measure?

For capacitors there is no point in going below 10p and above 100u. Likewise, the inductance range should be from 1uH to 10H. Below 1uH, the influence of the connecting wires will cause appreciable reading errors and so will stray capacitances below 10p.

The lowest standard values in our bridge will then be 100p and 10uH and the highest will be 10u and 1H0. A little calculation will show that a frequency of 15 kHz represents the best compromise. At this frequency, both the lowest induct (10uH) and the highest capacitance (10u) will have an impedance of approximately 1R0.

It will be relatively easy to design an oscillator which can deliver a small voltage into a 1R0 load. The requirements for such an oscillator are:

a) good frequency stability
b) a modest amount of harmonic distortion, say $\pm$ 1%
c) constant output voltage
d) low-power output capability
e) symmetrical output, isolated from earth
f) simple circuitry.

These requirements can be met by using a standard op-amp, a Wien bridge oscillator and an external complementary output stage.

The Bridge

The working principle of a measuring bridge is illustrated in Fig. 2. The two resistors marked R are equal in value, R_{cal} is the calibration resistor, R_x is the resistor whose value is being measured and M is an AC meter. When the voltages at A and B are equal, the bridge will be in equilibrium and the meter will read zero. This will occur when R_{cal} is equal to R_x, so if a calibrated scale is provided for R_{cal} the value of R_x can be read directly from it.

There are several possible circuit arrangements for a

HOW IT WORKS

The circuitry around IC1 is a Wien-bridge oscillator with an external complementary output stage. The stabilising element in the negative feedback path could be an RA 53 thermistor, but this is rather expensive, so a combination of silicon diodes and resistors has been used. The configuration is simlar to the CA 3019 and gives excellent results as far as distortion and output stability are concerned.

Diodes D5-D8 form a bridge, which is stabilised by means of a series combination of resistor R7, diode D9 and zener ZD1. R5 and RV1 are shunted across the bridge and determine the onset of oscillation.

The oscillator frequency is fixed by R2, C4 and R3, C3, both networks having a period of 10.4 us. The output voltage is 3.9 V with rather better than 1% THD.

To feed the measuring bridge, 0.5 V RMS will be amply sufficient, and this supply voltage must be symmetrical to earth. An 8:1 transformer enables us to meet these requirements. The worst case loading on the secondary of this transformer is Z = 1 ohm. This impedance, when transformed into the primary, is equivalent to 64R. The output current is then 62.5mA and P_{out} = 250mW.

This is beyond the capabilities of the CA3140 so a low impedance output stage is required, the simplest solution being a complementary pair of NPN/PNP transistors such as the BC 548B/558B.

The complementary pair is designed as a separate unit with biasing current through R7, R8 and D10, D11. There is no quiescent current in Q1, Q2, but the transistors are on the verge of conduction.

Oddly enough, this gives best results on heavy loads, and the arrangement provides a slightly lower harmonic distortion — 0.8% for Vout = 3.8 V RMS. The reason is that the distortions in the CA3140 and the complementary pair partly cancel.

The output of T2 feeds into the bridge itself, the network consisting of R9 and 10, RV2 and the switch-selected standard capacitors, C8-13 and standard inductors, L1-6. RV2 balances the bridge and has its wiper connected to ground. Since capacitive reactance falls with frequency and inductive reactance rises with frequency, the X and CAL positions for these two components are the reverse of one another if the 0.1 to 10 balance scale is always to read in the right direction. For this reason, the standard capacitors are connected to one arm of the bridge and the standard inductors to the other.

Any voltage appearing when the bridge is out-of-balance will be fed via the potential divider R11/R12 into the non-inverting input of IC2, another CA3140 op-amp. A potentiometer, RV3, has been included in the gain setting network so that the sensitivity of the measuring amplifier can be reduced during initial balancing of the bridge. Another diode bridge, this time consisting of germanium diodes, drives the meter from the output of the op-amp.

The power supply is conventional in every respect. A centre-tapped transformer, T1, feeds four rectifiers in a bridge arrangement to provide positive and negative rails, each of which is provided with a single 470u reservoir capacitor. Two further electrolytic capacitors, C16 and 17, are included to aid smoothing and decouple noise, etc. picked up on the supply rails.

PARTS LIST

RESISTORS (all 0.3W 5% film unless otherwise stated)	
R1	470R (not needed if LED1 has integral resistor)
R2, 3	6k8 1%
R4	3k3 1%
R5, 6	6k8
R7	3k9
R8	4k7
R9, 10	470R
R11	820k
R12	3M3
R13	100R (or 220R — see Buylines)
RV1	500R horizontal skeleton preset
RV2	10k linear wirewound potentiometer
RV3	5k0 Linear potentiometer (or 10k — see Buylines)
CAPACITORS	
C1, 2	470u 16V radial electrolytic
C3, 4	1n5 1% polystyrene
C5	22u 16V radial electrolytic
C6	470n talntalum
C7, 14	10u tantalum
C8	100p 1% polystyrene
C9	1n0 1% polystyrene
C10	10n 1% polystyrene
C11	100n 1% (see text and Buylines)
C12	1u0 1% (see text and Buylines)
C13	10u axial electrolytic (see text)
C15	1u0 polycarbonate or tantalum
SEMICONDUCTORS	
IC1, 2	CA3140
Q1	BC548B
Q2	BC558B
D1 – 4	1N4002
D5 – 11	1N4148
D12 – 16	0A91
ZD1	5V1 400nW zener
LED1	Panel-mounting red LED
MISCELLANEOUS	
L1	10uH (Toko 144LY – 100)
L2	100uH (Toko 144HY – 101)
L3	1mH (Toko 181LY –102)
L4	10mH (Toko 181LY – 103)
L5	100mH (Toko 181LY – 104)
L6	1H0 (Toko 239LY – 105)
M1	100uA panel meter (or 50uA — see Buylines)
SK1 – 3	4mm binding post terminals or similar
SW1	SPST miniature mains toggle switch
SW2	1 pole, 12 way rotary switch (see text)
T1	6-0-6V, 3VA PCB-mounting mains transformer
T2	Philips P22/13 pot core (or equivalent) with 120 turn primary and 15 turn secondary (see text).

PCB; case, Teko Desko TEK 363 or similar; knobs; mains cable and strain relief bush; nuts, bolts and pillars to support PCB; solder pins, connecting wire, etc.

measuring bridge, the two main ones being illustrated in Fig. 3. The arrangement shown at (a) is the simpler method because it is not symmetrical about earth and does not therefore require a transformer to couple it to the output from the AC generator. The circuit shown in Fig 3b is symmetrical about earth and does require a transformer but it is far less likely to suffer from the effects of stray capacitance. This is the arrangement which is used in this design, and the stray capacitance in the prototype is below 2p0.

There are six capacitance ranges and six inductance ranges on the prototype. It is not difficult to extend the bridge to measure resistance as well but this makes the range switching rather complicated and pushes up the cost.

A simpler alternative is to omit one of the standard capacitors. The range switch can be set to this blank position and an external decade resistance box connected in the L_X position, between the L and common terminals. An unknown resistance can then be connected in the C_X position (between the C and common terminals) and measurements carried out in the normal way.

Since electrolytic capacitors larger than 10u are difficult to measure accurately without a polarising current, the 10u range is of limited value only. It can safely be discarded to leave a blank position, and if a high capacitance range is ever required a 10u capacitor can be connected externally.

The Measuring Amplifier

With a 500mV input to the bridge, a sensivity of 10 mV full scale will be more than sufficient: a difference of 0.1 mV (1/100th of the full scale deflection) can still easily be seen. This means a maximum sensivity of 1 part in 5000 (500 mV/0.1 mV). If the diameter of the calibrating scale for RV2 is 90 mm (235 mm scale length), 1 part in 5000 averages 0.047 mm. Are your eyes good enough to detect that small an increment?

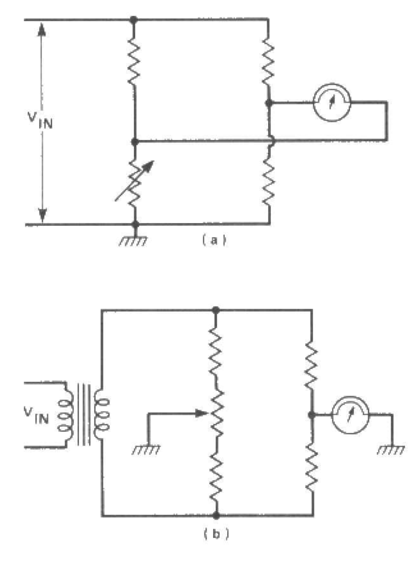


Fig. 3 Two possible bridge arrangements; a) one side earthed and b) symmetrical about earth.

The amplifier itself is another standard op-amp, here arranged as a voltage follower. A potentiometer is included to vary the gain of the stage, allowing the sensitivity to be reduced to make initial balancing of the bridge easier.

Construction

The prototype was built into a grey ABS case with a sloping aluminium front panel. Almost all of the components, including the mains transformer, mount directly onto the printed circuit board. The remaining components mount through the front panel and the PCB is supported against the underside of the panel. This makes for a neat and compact assembly, and the only construction work required on the other half of the case is to provide a hole and strain relief assembly for the mains cable to pass through.

The pot core must be wound with 120 turns of 34 SWG enamelled coper wire to form the primary and 15 turns of 24 SWG

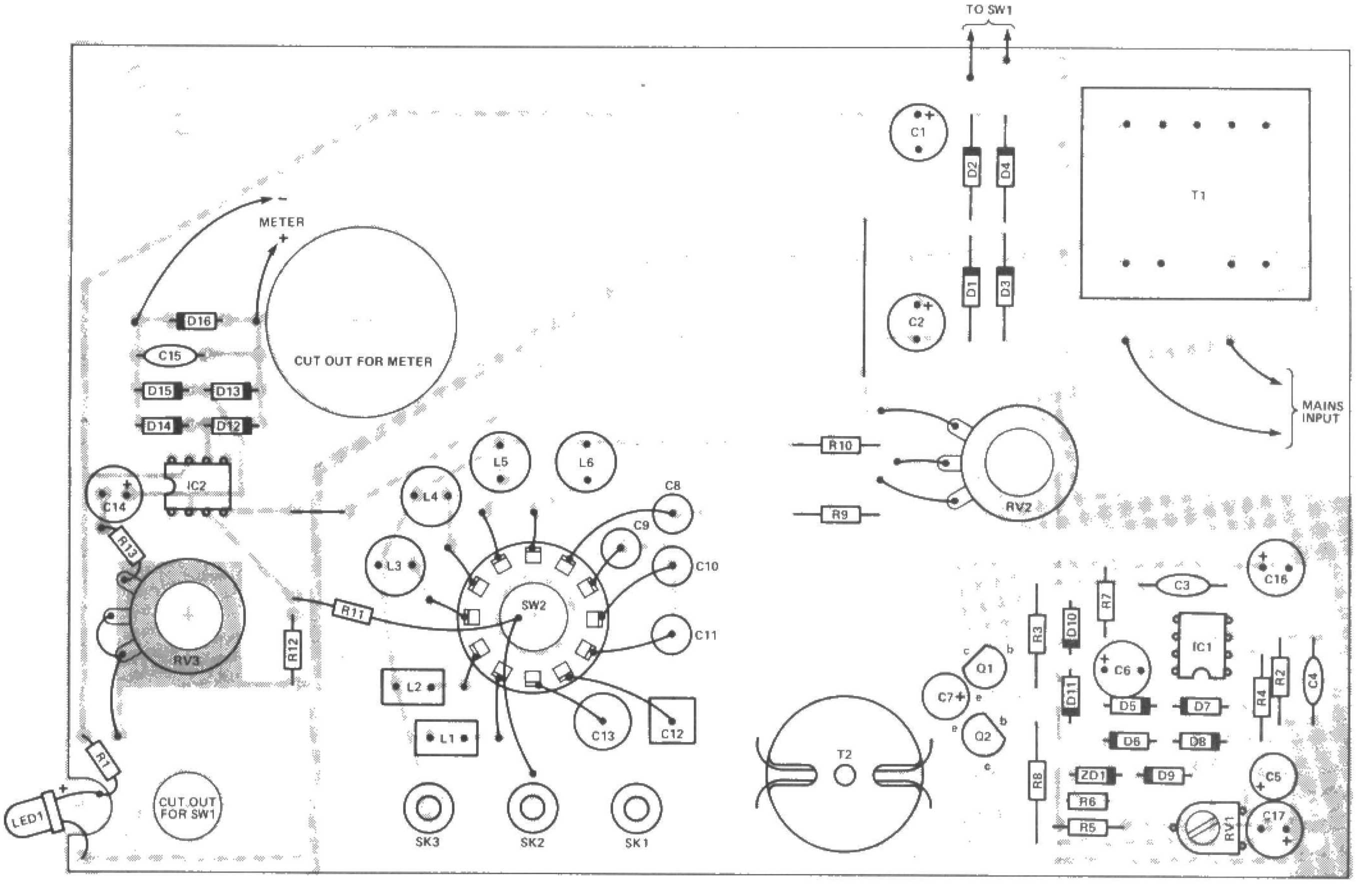


Fig. 4 Component overlay for the measuring bridge PCB. SK1-3 and LED1 mount through the front panel but have been shown here for completeness. Note that the potentiometers and the rotary switch are mounted on the PCB and that capacitors C8-13 are mounted vertically with their upper leads taken directly to SW2.

enamelled copper wire to form the secondary. Other pot cores could be used provided they have an inductance factor (A_L) of 250 nH/turn^2 or a turns factor (α) of 62.8 turns/mH.

Before starting to assemble the components onto the PCB, line-up the board behind the case front panel and mark and drill the necessary holes. It is a good idea to start with the holes for the two potentiometers and the rotary switch, then loosely assemble these components through the board and the panel to check that they line-up correctly. The board can then be clamped to the front panel using the switch and potentiometer mounting bushes while the remaining holes are drilled.

When the drilling is complete, begin assembling the PCB by installing the solder pins, the wire links, the IC sockets, SW2, the potentiometers, T1 and T2 and then the resistors, capacitors and inductors. Note that R15 is soldered into the board at one end and onto one of the contacts of RV3 at the other end. R11 must be soldered directly to the wiping contact of SW2 and kept away from other parts in order to keep stray capacitances to a minimum.

The standard capacitors C8-13 should be mounted vertically with one lead soldered through the board and the other bent over and taken to the appropriate switch contact. If you have been unable to find 1% tolerance 100n and 1u0 capacitors for C11 and C12, leave these positions blank for the moment. Once the rest of the bridge is working, it can be used to select suitably accurate components from standard 5% and 10% stock.

If you intend to use the bridge for resistance measurements, you have the choice of either modifying the range switching arrangements or simply omitting one capacitor as discussed earlier. If you choose the latter option, simply leave out C13 and remember when you come to label the front panel that the 10u range should be marked external instead.

When all of the other components have been soldered into place, the diodes and then the transistors can be added. The extended copper pads around the collectors of Q1 and Q2 are intended to help heat dissipation, and the collector leads should be trimmed to 4mm or less before soldering. The other two leads on each transistor can be made a little longer to ease installation.

The remaining components should now be mounted on the front panel, these being the meter, the LED, SW1 and the three binding post connectors. It is important that the connectors are well isolated from the panel so as to keep stray capacitances to a minimum. This will largely depend on the construction of the connectors themselves, so choose fairly 'meaty' types which have as much plastic insulation between the metal conductor and the panel as possible. If stray capacitance is a problem, try cutting a single large hole in the panel and mount the connectors on a piece of paxolin or other insulating material.

BUYLINES

The resistors, the semiconductors and most of the capacitors are available from companies advertising in these pages and from the other usual sources. The inductors are all available from Cirkit, and West Hyde Developments stock the Teko case. Electrovalue can supply the pot core, a winding bobbin and a PCB mounting kit for the assembly. Their order codes are B65661 L0250 A028 for the pot core, B65662 B0000 T001 or T002 for a single or double plastic bobbin, and B65665 C0004 X000 for the mounting kit. The pot core is available while stocks last at 60p, after which it will be replaced by a similar item, B65661 N0250 A022 which will cost £1.26.

Some of the 1% tolerance capacitors are available from Maplin but the 100n and 1u0 are not. Philips manufacture a range of polystyrene capacitors designated C424 and C444 which includes a 100n type, and constructors who have access to trade component suppliers may be able to obtain some of these. We do not know of any manufacturer who produces 1u0 capacitors with a tolerance of 1%. Both types can be substituted by gathering together a number of wider tolerance capacitors and then using the otherwise completed bridge to select the most accurate. The procedure is described in the text.

Although a 100ua meter is specified in the parts list, the prototype used a 50uA Micronta meter from Tandy. If this or any other 50uA meter is used, R13 and RV3 should be exchanged for the values shown in brackets. Nothing else should present any problems and the PCB is available from our PCB Service.

Attach the PCB to the front panel using four spacers and countersunk-head bolts. Solder a pair of leads to the points marked XX on the PCB and connect the other ends to SW1. Connect up the meter carefully observing polarity and also solder leads from the PCB to the three connectors and to the LED. Note that R1 will not be needed if you use a panel-mounting LED which has an integral resistor. Insert the two ICs into their sockets, making sure that they are the right way around.

Feed the mains lead through a hole in the bottom half of the case, secure it with a strain relief bush and solder the live and neutral leads to the pads near T1 primary. Connect the earth lead to the front panel by means of a solder tag under one of the PCB support bolts. This will reduce the effects of hand capacitance when testing small capacitors.

Calibration

Before starting the calibration procedure, the oscillator must be adjusted. This is done with the preset resistor RV1, which must be set such that the amplification factor is just a little above 3. If the gain is below 3, the oscillation stops altogether, and if it is too much above 3 the wave-form becomes very distorted. RV1 must therefore be set very carefully just a little above the point where oscillation starts.

If this point is not within the range of the preset, it will be necessary to make a slight correction to R5 (6k8). This can easily be done by shunting R5 with a high value resistor (on the copper side of the printed circuit board). In the prototype, 270k was just right.

An oscilloscope or a distortion meter will be very helpful here, but if these are not available just make sure that the oscillator output is 3.9V ± 2%. As a final test of correct working conditions, connect a 1R0 resistor across the secondary of T2. If the oscillator stops, the gain must be slightly increased by means of RV1.

Now we turn to the calibration. First we need a knob with a dial pointer, and this can be made from a piece of clear plastic glued to the underside of an instrument knob. You may be lucky enough to find a knob with threaded holes on the underside.

Make a provisional scale and tape it to the front panel, then turn SW2 to the free position. You will need nine precision resistors of 100R and one of 1k0, preferably all of 0.5% tolerance.

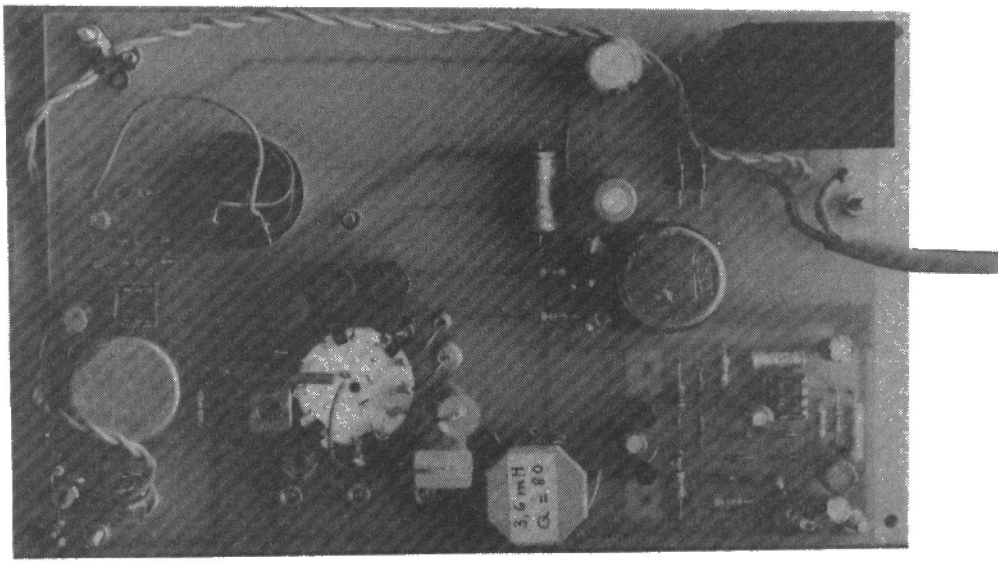
Connect a 100R resistor across C_X as the reference value and another 100R resistor across L_X. Adjust the calibration knob carefully to read a minimum on the meter and make a pencil mark on the scale. This will be the '1' position.

Next, connect two of these resistors in series across L_X, adjust the potentiometer for zero reading on the meter and mark a '2' on the scale.

Repeat the procedure with 300R to give the 3 position, 400R to give the 4 position and so on up to 10. Intermediate points can be found by using two 100R resistors in parallel as one series element, giving 1.5, 2.5, etc. To calibrate the other half of the scale, connect the 1k0 resistors across C_X as the reference and use series strings of the 100R resistors to obtain 0.1, 0.2 and so on and series-parallel chains to obtain the intermediate points.

If you were unable to find either or both of the 100n and 1u0 1% standard capacitors, you can now use the bridge to choose suitable examples. One method for selecting the 100n capacitor is to set the bridge to 10n and then test a batch of 100n capacitors until you find one which gives a reading sufficiently close to 10 on the scale.

A more accurate method is to connect several 1% 10n capacitors across the C_X connections and then select a 100n capacitor which gives a reading of 0.1 or 0.2 or whatever is appropriate for the number of capacitors you have used. The more capacitors (and therefore, the nearer their



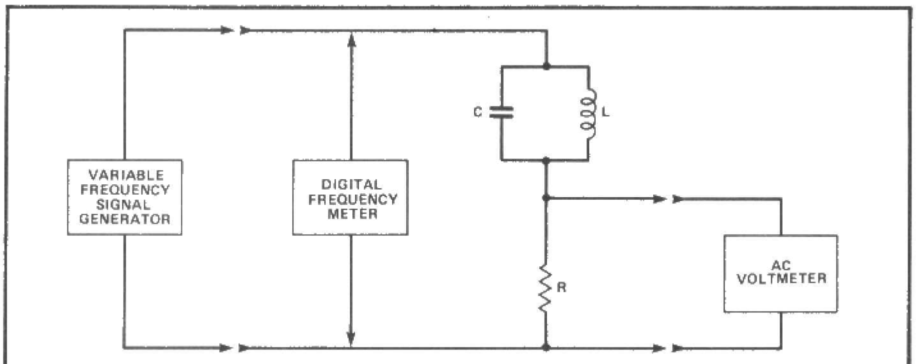


Fig. 5 Arrangement for making accurate measurements of inductance.

combined capacitance is to 100n) the more accurate the selection will be. Once the 100n capacitor has been selected, the process can be repeated to find a 1u0 capacitor.

The inductors specified in the parts list all have a tolerance of ±5% except the 1H0 coil which has a tolerance of ±10%. These are rather low levels of accuracy but are generally regarded as acceptable for inductors. In my opinion it is not really worth spending much time and effort improving on these figures, but if you particularly want a high level of accuracy then the following method should enable you to achieve it.

Figure 5 shows the circuit to be used. C is a capacitor of ±1% tolerance or better and R is adjusted according to the impedance of LC at a given frequency. The frequency generator should be adjusted for minimum reading on the AC voltmeter and the frequency then noted using the DFM. The value of the inductor can be calculated using the formula:-

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

Once the value of a particular inductor is known, it can be used to select other inductors by means of the procedure described for selecting capacitors.

Once the standard capacitors and inductors have all been soldered into place, the front panel can be secured to the bottom half of the case and a final calibrated scale prepared. It is a good idea to use a graduated arc and to plot a curve on millimetre scaled paper. This will reveal any serious errors arising from the calibration process and also yield a few extra intermediate points such as 1.1, 1.2, etc.

In use, the only point to remember is that there will be a residual capacitance of about 2p0 which should be taken into account when measuring small capacitances.

ETI

ETI SORCERER STRING SYNTHESIZER

Contrary to popular belief, writes designer and author Graeme Durant, a string synthesizer is not a machine for making twine. Relax and unwind as the yarn unfolds.

The string synthesizer originated in the 1970s, and perhaps owes more to organ developments than synthesizer technology; the basic instrument being polyphonic with preset sounds, usually generated by an organ-type frequency divider, gating and filtering, followed by a chorus generator to enhance the massed string quality.

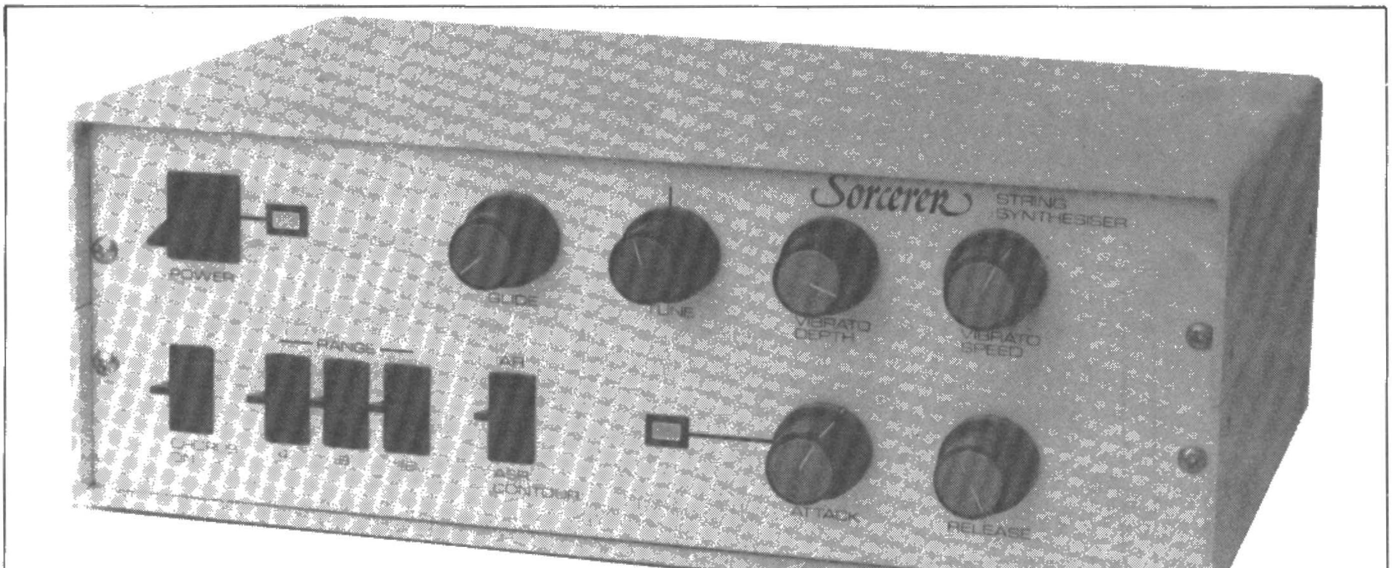
Although the string synthesizer is very commonly used in many types of music today, due to its unique ability to fill out the sound of a small band without being too forward, it is usually used as a backing instrument to other keyboards. So, with an average sort of selling price in the order of four hundred pounds for a commercial unit, the string synthesizer is often out of the reach of many amateur musicians, as a mere second instrument.

That is where the ETI Sorcerer comes in. For a mere fifty pounds outlay, the Sorcerer provides this lush backing sound albeit in monophonic form only, but with sufficient power to produce very emotive backdrops.

Facilities

The ETI Sorcerer is unlike most commercial synthesizers in that it is built along the lines of a general purpose analogue synth, using similar circuit blocks such as VCOs and envelope generators. Its variable controls also mirror some of those more often found on analogue synths, providing great versatility and many sound options apart from the more usual string effects.

The basic keyboard is a three octave unit, but Sorcerer provides three switches akin to organ stops, which allow individual or simultaneous selection of three one octave spaced ranges. Selecting all three ranges allows an effect like holding down a bass note, a note an octave up and a note two octaves up. The results are extremely powerful. A glide



The Sorcerer processor.

control allows slewing between played notes and a fine tune control means Sorcerer can be tuned to other instruments. A vibrato effect is included, and controls are available to adjust its speed and depth. There is also an envelope contour generator with variable attack and release rates.

To simulate strings it is not necessary to go to the expense of using a full ADSR envelope generator, as on most analogue synths. An AR generator with a 'sustain on/off' switch is perfectly adequate. To produce the effect of massed instruments, a powerful chorus generator is included in the unit, which can be bypassed if desired for solo playing. The Sorcerer has a line output for an amplifier and a high impedance headphone output for use during recording.

The keyboard is a touch operated unit, chosen primarily for reasons of economy. A conventional keyboard can be used if preferred and the budget allows.

A three octave range is provided for by a PCB keyboard with full width keys. Being electronic, it has been designed to delay its response slightly to simulate the time usually taken for key travel and to ensure reliable detection of touch. As a result, it will not respond to fast playing, but this was not considered a particular disadvantage since Sorcerer was designed for slow backing-type use anyway. The keyboard includes circuits which detect when more than one key is being pressed. These provide a sort of multiple trigger function, similar to 'two key roll-over' found on computer keyboards, so that as long as only one key is pressed, it will be the one which is sounding.

Block Diagram

Sorcerer is built up on six printed circuit boards with a separate power supply board. This allows a modular construction and the possibility of adding new modules for special effects. The keyboard forms two of these boards, producing a key voltage proportional to musical pitch and two timing signals — gate and trigger.

The key voltage goes on to the VCO board. This board centres around a precision voltage-to-frequency converter which outputs a pulse train at a multiple of the desired frequency. A low frequency oscillator provides the modulation for vibrato. The pulse train is divided in frequency to the three required pitches, at one octave spacings, and the square pulses resulting are given the required width characteristics. After passing through octave selector switches, the three signals pass on to the chorus boards. Here, the three signals are individually filtered to produce sounds closer to strings, and then mixed to form one composite signal. The signal is fed either via parallel delay lines to gain a heavy chorus effect or directly off board if the chorus mode is not switched in.

The signal now reaches the final processing board, the envelope circuits. These give the signal the desired amplitude contour for the synthesis and allow variation of the amplitude attack and release rates, as well as selection of the sustain time. Synchronization is obtained from the trigger and gate signals from the keyboard. The output is then buffered and sent to the output jack, and to a low-power amplifier suitable for driving high impedance headphones.

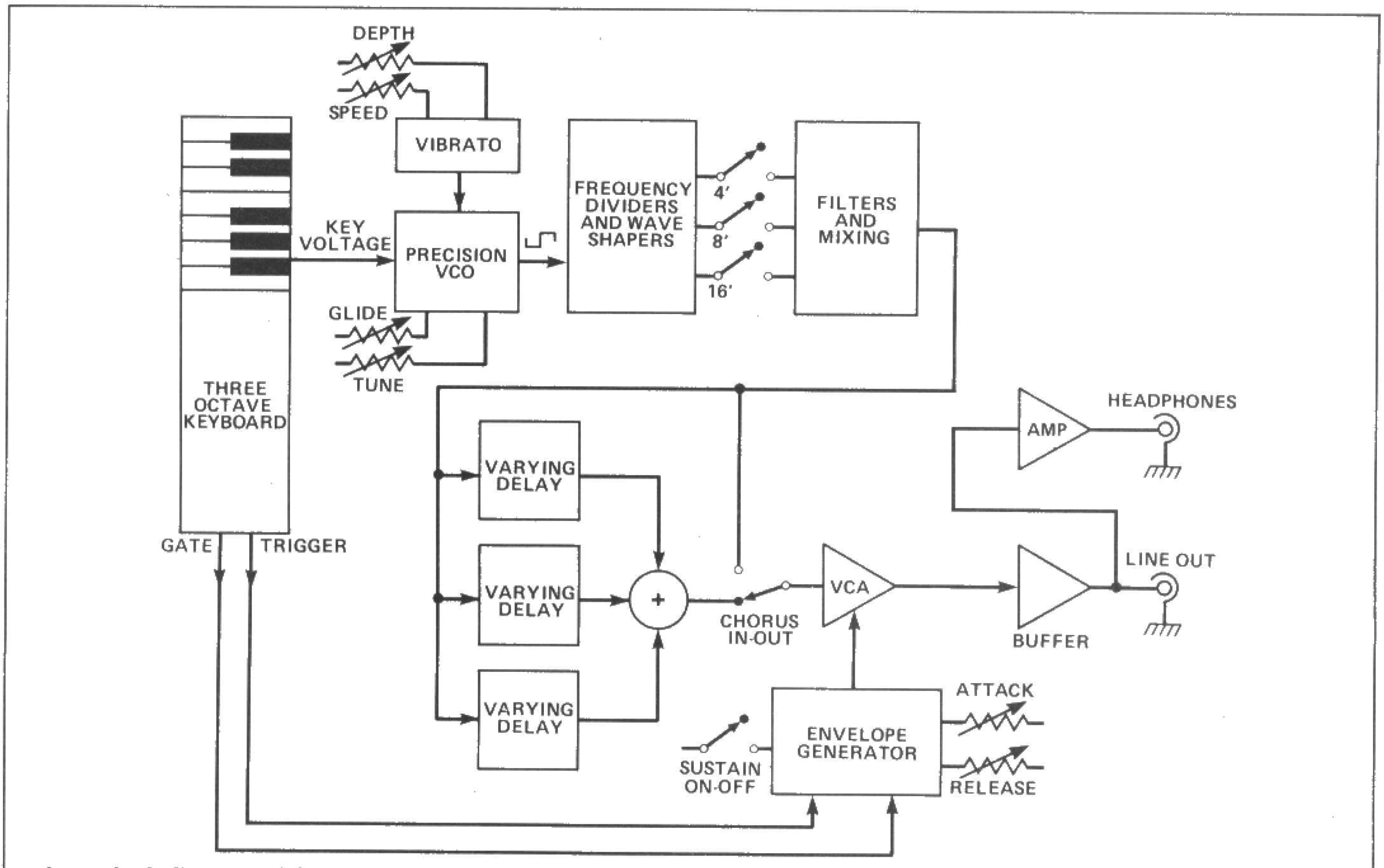


Fig. 1 Block diagram of the Sorcerer.

HOW IT WORKS
VCO SECTION

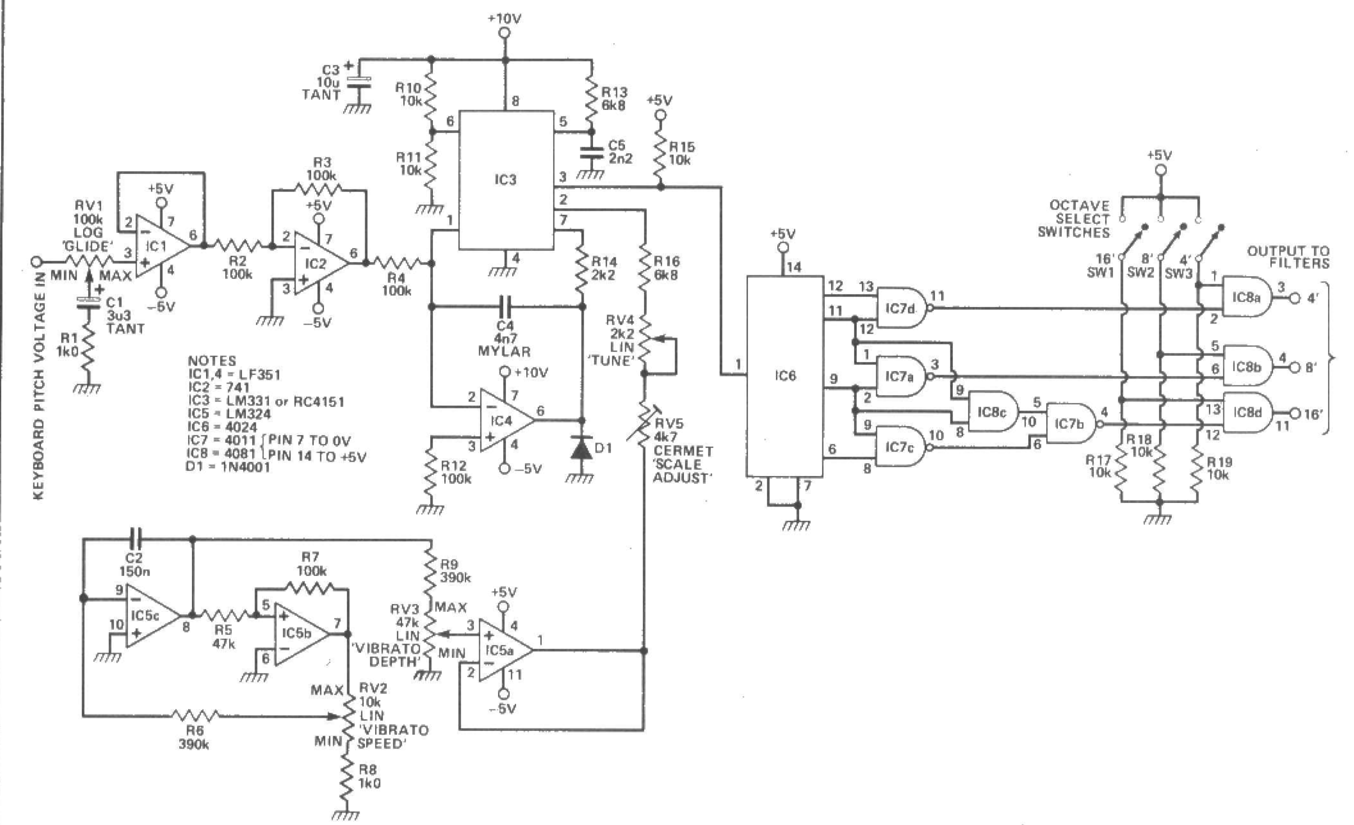


Fig. 2 Circuit diagram of the VCO section.

In Sorcerer, the VCO circuits are primarily concerned with converting the keyboard pitch voltage into a proportional frequency output. They also provide the facilities for glide and vibrato, and generate three one octave spaced pulse train outputs, with the correct mark-space ratios.

The keyboard pitch voltage is applied to one end of RV1, the glide control. C1, a low leakage tantalum capacitor at the slider of RV1, provides the required variable slewing between notes. The other end of RV1 goes via buffer to the rest of the circuit. The buffer, IC1, is required so that the glide control sees a very high impedance (about 10^{12} ohms) otherwise the pitch of the VCO would be affected as the glide control was adjusted. The pitch voltage is then inverted by IC2 wired as a unity gain inverting amplifier. This is necessary since the voltage-to-frequency circuit used requires a negative input voltage.

The voltage-to-frequency converter circuit is based around IC3 and IC4. IC3 is either an LM331 or equivalent RC4151 which is somewhat cheaper. IC4 is another LF351, this time chosen for its low input offset current, and is wired as integrator. A simplified circuit is shown in Fig. 3.

The output voltage of IC4 goes go one input of a comparator inside IC3 at pin 7. The other input, pin 6, goes to a circuit point at half the supply voltage. When the voltage at pin 7 is the greater, the comparator triggers the one-shot timer. This will turn on both the frequency output transistor and the switched current source for a time $t = 1.1R_tC_t$. During this time, a current i will flow out of pin 1 into the input of the integrator. The integrator output will start to ramp down. This current will have an average magnitude of $I_{av} = itF$, where F is the frequency of oscillation. This average current perfectly balances the current due to the input voltage, $-V_{in}/R_{in}$, at the integrator's virtual earth input. At the end of the one-shot timing period, the current source and the output transistor are both switched off. The integrator output will start to ramp positive again, until it exceeds the voltage at pin 6 of IC3, when the cycle will start again.

The frequency of oscillation can be determined from the balanced input current:

$$-V_{in}/R_{in}=I_{av}$$

but

$$I_{av}=itF$$

and

$i=V_{ref}/R_s$ which equals $1.9/R_s$, since $V_{ref}=1.9V$ and is internal to IC3.

Also:

$=1.1R_tC_t$ so that $F=-(V_{in}/2.09).(R_s/R_{in}).(R_tC_t))$ and F is proportional to $-V_{in}$.

In our case R_s is made up from R16, RV4 and RV5. The latter two variable resistors make for fine and course tuning respectively. Instead of connecting the end of R_s to ground, it is fed from a buffer IC5a, driven by a variable low-frequency and variable amplitude triangle wave generator. This standard integrator-Schmitt trigger oscillator generates a triangle wave which is symmetrical about 0V. It slowly varies the frequency of the VCO, cyclically about its programmed pitch, by adjusting the current flowing through R_s. This provides the vibrato function.

The frequency output of IC3 at pin 3 is divided by 2, 4, 8, and 16 at pins 12, 11, 9 and 6 and IC6 respectively, a CMOS ripple counter. These outputs pass through IC7 and IC8c, which convert the squarewave signals to pulse waves with a 25% duty cycle at the 4' and 8' outputs and with a 12.5% duty cycle at the 16' ouput. These particular pulse widths have harmonic contents which much more closely approximate the sound of a violin and cello respectively, and are thus used for the basis of these sounds. The outputs are switched electronicaly using IC8a, b, and d, via front panel switches SW1, 2, and 3, to save routing signals to the front panel. The three, octave-spaced, signals pass on to the filter/chorus boards.

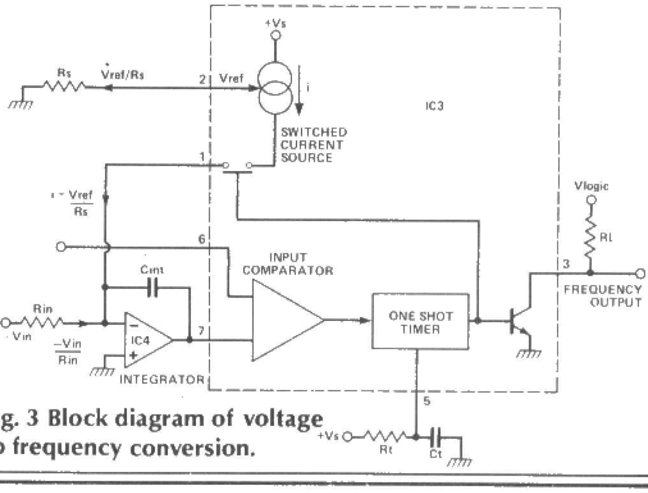
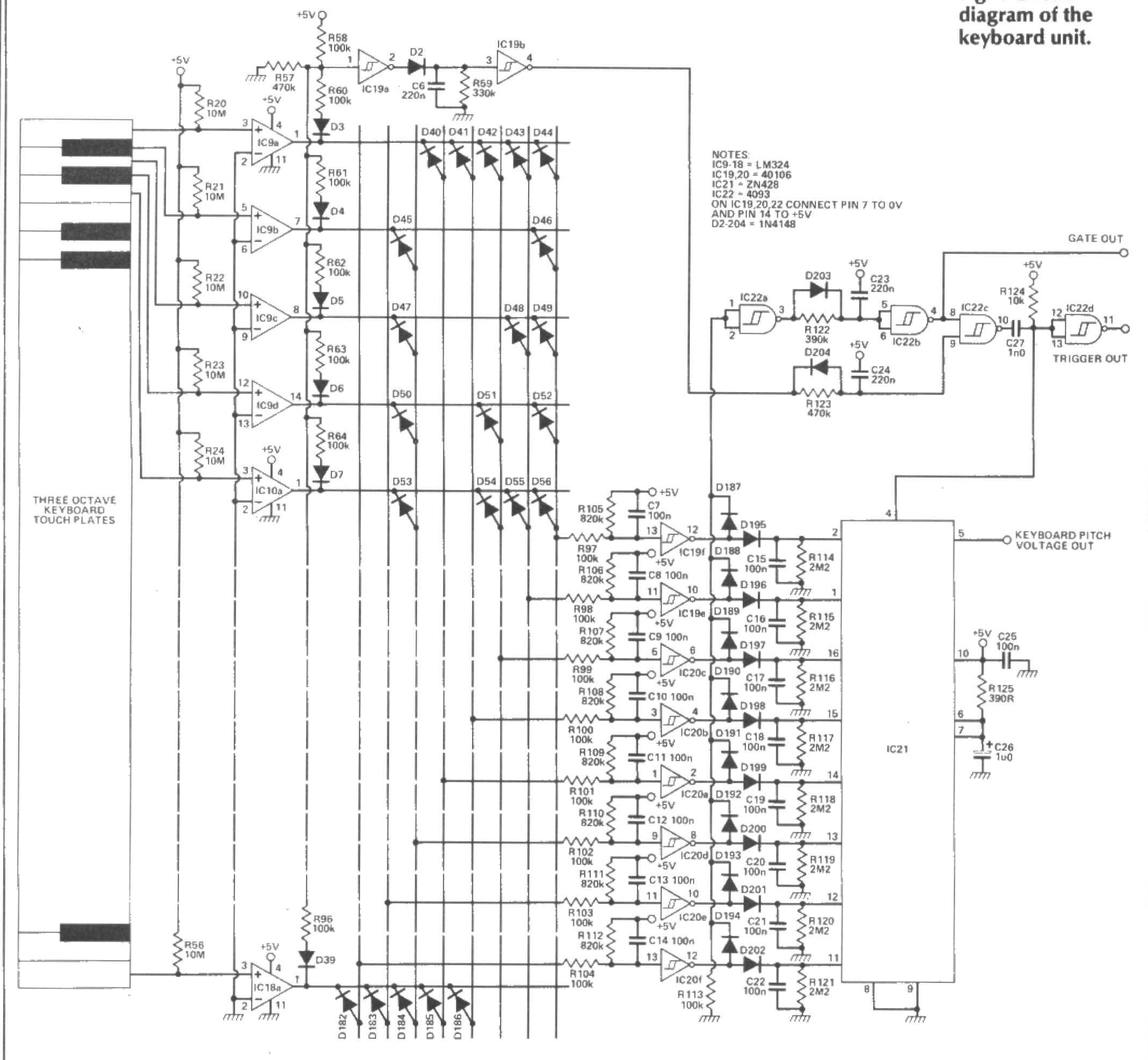


Fig. 3 Block diagram of voltage to frequency conversion.

HOW IT WORKS
KEYBOARD UNIT

Fig. 4 Circuit diagram of the keyboard unit.



The keyboard unit must take an input from the musician paying the keyboard, and produce information from the key operated, to tell the rest of the synthesizer what to do, and when to do it. This information is a voltage, proportional to the frequency of the required pitch, a trigger pulse produced every time a new note is operated and a gate pulse signal which is a local high for the duration of any key press.

Suitable touch switches come in three types, with different principles of operation. The simplest is the resistive type which detects the change of resistance between two contacts bridged by the fingers. This method was used some years back in an ETI project for a miniature organ keyboard. Although simple, it has serious drawbacks — it is disabled by moisture and does not respond to musicians with dry skin! A much better, but more complex technique is to use the principle that a human body acts just like a small value capacitor with one end grounded, using a finger as the other connection. Such designs usually employ a high frequency oscillator and moderately complex detection circuits — not really suited to being reproduced thirty seven times on a keyboard! The technique chosen for Sorcerer uses hum-detection. The human body acts like a sort of aerial, picking up mains hum which can be detected using a high input impedance amplifier.

Each key is formed by an area of copper on the keyboard PCB, is linked to the non-inverting input of a low-power op-amp and held to the supply voltage by a very large resistor. When the keys are untouched, the resistors pull the non-inverting inputs above the voltage of the inverting inputs, each tied to 0v, and so the op-amp outputs are high. When a key is touched, a 50Hz signal is injected into the non-inverting input of the appropriate op-amp. Since the op-amps are used here as large gain comparators, the output is in the form of a 50Hz pulse train between 0V and 3.5V which must be detected.

Each key is encoded with an eight-bit binary number which will eventually go for digital-to-analogue conversion. The coded numbers must be proportional to the required pitch voltages.

The relationship between the frequency of the successive notes on a musical keyboard is exponential not linear. Each octave is a doubling in frequency and adjacent notes are multiples of the twelfth root of two in frequency! The usual method used in analogue synthesizers to achieve this musical scale is to design a keyboard which produces a linear voltage output, often a standard 1 volt/octave, passing this to a special VCO which responds in an exponential fashion. Thus, a simple keyboard is used to control a very complex and expensive VCO. The linear to exponential conversion technique is very prone to the effects of temperature change and component mismatch. If it can be avoided life becomes much simpler!

Sorcerer solves the problems

KEYBOARD UNIT

of stability and complexity at the price of precision. The keyboard produces an exponentially incremented pitch voltage output, using a series of exponentially related binary keycodes, and drives a linear VCO. Being digitally generated, the keyboard output is very stable, but since it is only limited to eight-bit precision, the voltages have small — but normally unnoticeable — errors referred to the exact voltage required.

The binary codes are programmed using a diode matrix. The key op-amp outputs are connected, where required, to the eight-bit data bus by reversed signal diodes D40 to D186, forming the exponential code (Table 1).

The data on the data bus is still in form of 50Hz pulse trains and must be made into steady logic levels to drive the digital-to-analogue converter. The signals on the data bus are low-pass filtered by R97 to R112 and C7 to C14 to remove the 50Hz component, and drive CMOS inverting Schmitt triggers in IC19 and IC20. If a data line is inactive, the input to the Schmitt is held high by one of R105 to R112. An active line produces a high at the Schmitt trigger output, and an inactive line a low.

The resulting steady codes are passed on to IC21, an eight bit digital-to-analogue converter, to be changed into the output pitch voltage. Diodes D195 to D202 and storage capacitors C15 to C22 ensure that data is valid even if a key is operated for less time than it takes the DAC to latch.

The gate signal is produced by using an eight input diode OR gate (D187 to D194 and R113) connected to the eight logic level data lines. Pin 3 of IC22 will go low when any key is pressed. A delay is produced on this falling edge by R122, D203 and C23, so that the output of IC22b will go high shortly after any key is pressed, giving the data lines time to settle down.

D3 to D39 and R60 to R96 feed a filter-Schmitt trigger circuit using IC19a and b, the output of which will go low if two or more keys are pressed at the same time inhibiting the trigger and latch. This signal has its rising edge delayed by R123, D204 and C24, so that the data lines can settle down when two keys are pressed simultaneously and one is then released.

IC22c, C27 and R124 produce a negative pulse when there is a change from no keys or more than one key being pressed. This pulse is used to update the digital-to-analogue converter latches, and in inverted form, via IC22d, used as the trigger signal for the envelope generator.

NOTE	EXP. COD	BINARY CODE
C	31	00011111
C#	33	00100001
D	35	00100011
D#	37	00100101
E	39	00100111
F	41	00101001
F#	44	00101100
G	46	00101110
G#	49	00110001
A	52	00110100
A#	55	00110111
B	59	00111011
C	62	00111110
C#	66	01000010
D	70	01000110
D#	74	01001010
E	78	01001110
F	83	01010011
F#	88	01011000
G	93	01011101
G#	98	01100010
A	104	01101000
A#	110	01101110
B	117	01110101
C	124	01111100
C#	131	10000011
D	139	10001011
D#	147	10010011
E	156	10011100
F	166	10100110
F#	175	10101111
G	186	10111010
G#	197	11000101
A	209	11010001
A#	221	11011101
B	234	11101010
C	248	11111000

Table 1 Sorcerer keyboard binary key codes.

Usually, one of the most critical parts of a music synthesizer is the power supply unit. In an analogue design most of the synthesizer parameters are supply dependent. A professional machine must have a drift free tuning, and as a consequence the power supply design is very complex.

This is not the case in Sorcerer. All critical parts of this design have local references of their own, most based on very stable band-gap devices in the ICs used. Thus a simply regulated supply is all that is required.

Sorcerer requires three power rails to run, and all of these are mains derived. A dual secondary 9V transformer, rated at 8 VA is used as a source. This is conventionally rectified and **smoothed by BR1, C28 and C29. IC42 provides a +5 volt regulated output, and IC43 a −5 volt supply. The other supply required is a +10 volt output.** Since it is not common to find **fixed ten volt regulators, a low** current 5 volt device, IC44, is **stacked on top of the main +5** volt rail. D205 ensures that the IC **starts up correctly when driving a capacitive load.**

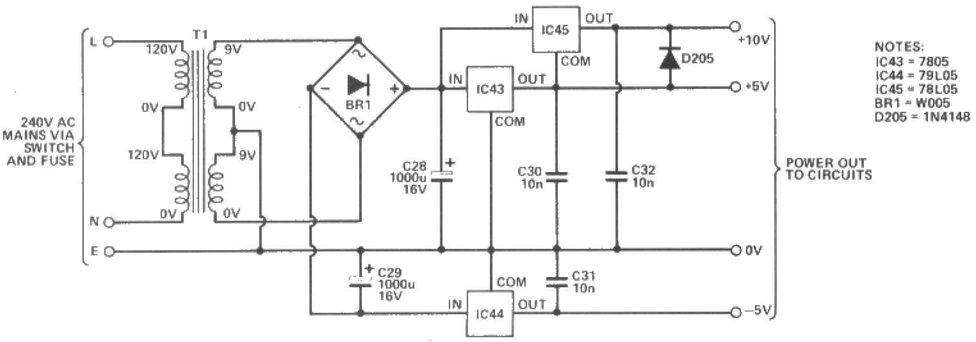


Fig. 5 Circuit diagram of the PSU

Since the Sorcerer is a project of considerable length, we have been obliged — for reasons of space — to split it up into a number of parts. The circuit diagrams and descriptions of the envelope shaping and chorus sections of the synthesizer will appear next month. We hope to publish the PCB foil patterns and component overlays the following month, along with constructional details, information about modifiying the circuit for use with a conventional keyboard, details of the setting-up procedure, parts list and Buylines.

ETI

EX42 INTERFACE FOR THE BBC 'B'

In response to a flood of readers' queries, we present a project devised and typed by Philip Ashby using a BBC computer and an EX42 daisywheel typewriter, in which he tells us how he did it.

In ETI, October 1983, we featured an interface that enabled a Silver Reed EX 42 electronic typewriter to convince itself it was a computer printer. The economic arguments for using a typewriter rather than forking out for a daisy-wheel printer are still just as valid — and you get a good quality keyboard thrown in as well!

For this author, the interface in its original form proved capable of many hours of trouble-free listings when coupled to a Jupiter ACE. The home computing capacity has since been upgraded to a BBC B, and with that came the promise of more work for the EX42: not just listings but text print-outs, too, from the word-processing package. A couple of extra ICs and 180 or so bytes of machine code make for a conversion kit, to give compatibility with the Centronics port on the Beeb.

Repeat

The basic interface remains intact (Fig. 1), so if you don't have the board go scurrying back to October 1983's ETI, p21. To recap briefly: the processor inside the typewriter scans across an 8x8 matrix of switch contacts in the keyboard, looking to see which of the 8 horizontal lines has been connected to a vertical one. It does this by sending successive voltage pulses down each vertical and looking for them on the horizontals.

Connections run from the interface to each of the keyboard matrix lines in the typewriter. The interface 'fools' the typewriter's processor into thinking a physical contact has been made on the EX42 keyboard by mirroring the scanned pulse from an X line into the appropriate Y line.

Between them, the computer and interface have two major jobs: code translation (from output ASCII to a 6-bit code for the keyboard matrix) and overall control of data flow via the handshake lines.

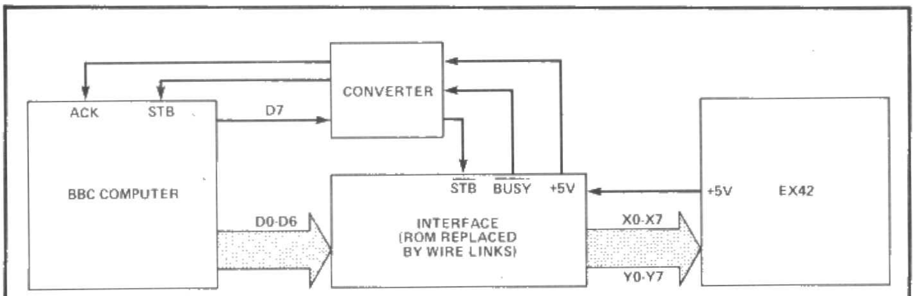


Fig. 1 Block diagram of conversion for original interface.

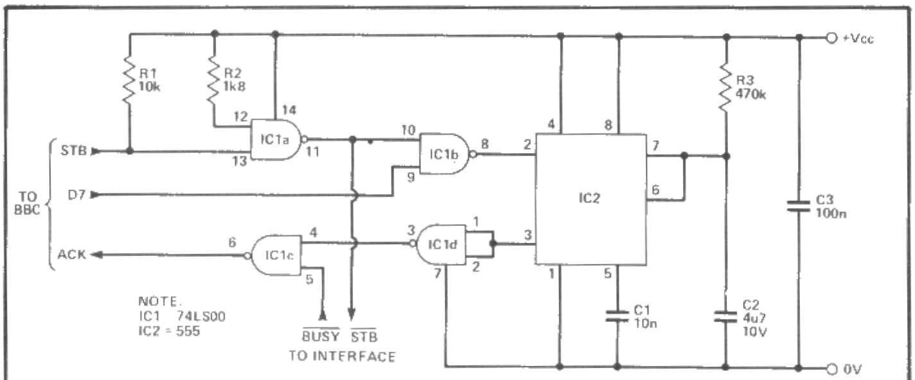


Fig. 2 Circuit diagram of conversion hardware.

HOW IT WORKS

IC2 in Fig. 4 forms a monostable timer with a period adjusted by R2 to approximately 2s. When triggered, it produces a positive pulse. The trigger to the timer is the output on D7 from the computer, gated with STROBE through the NANDs, ICla and Ib. The timer will trigger with D7 at logic 1 and STROBE on a negative-going edge going low. Output of the timer then extends the the ACK pulse to 2 secs: otherwise ACK is the logical inverse of BUSY from the interface and would be high for about 100ms. The theoretical timer period is 1.1 x R_3 x C_2. Adjust R_3 if the actual period is too long or too short.

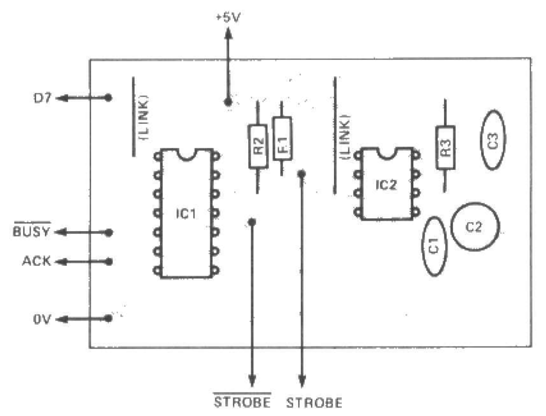


Fig. 3 Component overlay for conversion hardware.

Shake On It

There are two handshake lines between the interface and the computer (STROBE and ACKNOWLEDGE on the BBC Micro) and, as a first job for the adaptor, their polarity needs to be inverted.

The handshake lines work like this: the parallel printer port on the Beeb will pulse STROBE down to 0V when a set of valid data (the next character) exists on the lines. The data stays the same until the return handshake on ACKNOWLEDGE. The protocol for ACK is to go negative when the printer has done its work. (For those readers expecting a line called BUSY, it exists as a contact pin on the socket of the Beeb, but it isn't used for control purposes.)

Number Crunching

The translation from ASCII to keyboard code in the modified design is done by software in the micro, and data lines DO to D5 carry the translated information. D6 is used to signal a shift character to the typewriter, and D7 to indicate when a carriage return is being sent. The latter logic signal is used to trigger a 2s delay in the ACK pulse, to allow the printer head time to travel back to the left hand margin. It's strictly from the 'dirty tricks' side of electronic design: one 555 timer chip in hardware doing the job of several lines of software!

In contrast, software translation of ASCII to keyboard code was preferred because of the options available for future expansion — different character sets (if, say, you save up your pennies for a new daisy wheel), or specials such as underlining. Software, like life, is never as simple as you hope, and two obstacles hit you straight away. BASIC won't suffice if you want to output text when in word-processor mode. Resident ROMs within the computer such as VIEW and WORDWISE have the rather nasy habit of doing fairly powerful rearrangement of memory to suit their own ends when storing text. The driver software has to be in machine code and, together with the translation table, be tucked away in memory out of reach of the word-processing program. They are listed here as programs in BASIC to generate the translation table and machine code routine, and then relocate them. Generation need only be done once for any one version of the character code.

The location to store the program in is page C: COOh to CB8h. This is normally used to store the fonts for extended character sets, so it's rather unlikely that it will ever clash with print demands from the EX42 — unless you have a particularly exotic set of daisy-wheels!

The advantage of this lcoation is that the area is not grabbed by

PARTS LIST

RESISTORS (all 5%, ¼W)	
R1	10k
R2	1k8
R3	470k
CAPACITORS	
C1	10n mylar or disc ceramic
C2	4u7
C3	100n mylar or disc ceramic
SEMICONDUCTORS	
IC1	74LS00
IC2	NE555N
MISCELLANEOUS	

26-way IDC connector and ribbon cable; PCB; thick gauge wire.

SOFTWARE

The software falls into three main areas: generation of the translation table; generation of the machine code translation program; and a routine to load these programmes and modify vectors used by the Operating System so that the programs are called when appropriate.

Listing 1 generates the translation table, the data for which is printed as Listing 2. The programme prompts you to enter the codes for each ASCII character, display the results, and assembles the code into an array called TABLE. The array is then stored in a file known as chars. Readers with utility programmes resident in their machines would obviously have quicker ways of locating the table in memory and storing to disc.

Lines 10 to 30 set up addresses used for temporary storage of registers and a value used later for a call to a routine in the Operating System (an OSBYTE call). Line 50 sets the compilation address of the code, and lines 40 to 70 set up the BASIC assembler for two passes. When the programme is activated, it will be entered whenever the computer wishes to store a character (held in a register) into a buffer. This is accomplished by changing the value of a vector used by the operating system, resident at 22Ah. The Operating System identifies the required buffer with a value in the X register held on entry to the routine. The value is 3 for the case of the print buffer, and this is checked by line 100, with branching on line 110.

If the print buffer is requested, the next job is to check whether it is full before attempting to fiddle the character! Lines 130 to 180 perform this task, and all being well, lines 190 to 220 make the change, using the code-table stored from OCOOh to translate the character.

The rest of the program restores various registers and assembles routines for the remaining branches. The address JUMPed to in line 260 is that of the original buffer routine.

Listing 3a is the BASIC program that assembles the translator machine-code program.

Listing 3b shows the screen display when the program is RUN and the code compiled. After compilation, type in *SAVE "mc" OC81 OCB3 to store the machine-code program.

You now have two files, "mc" and "chars" stored on tape or disc, and Listing 4 loads both of them into memory. It also activates them by inserting the program address (OC81h) into the vector location in memory (22Ah) used by the Operating System for buffer operations. For convenience, this has been created as a !BOOT file, assembled on disc, which will load and run on a SHIFT-BREAK. On completion, in this case, control is handed over to VIEW for word processing.

```
 10 CLS: PRINT TAB(5,5) "ASCII CHAR"
 20 DIM TABLE(128)
 30 FOR A=0 TO 31:TABLE(A) = 16:NEXT A
 40 TABLE(10)=137
 50 TABLE(13)=137
 60 FOR A= 32 TO 128
 70 PRINT TAB(5,7) SPC(15)
 80 PRINT TAB(5,7); A;SPC(5);CHR$(A);
 90 INPUT  AI
100 TABLE(A) = AI
110 NEXT A
115 C = OPENOUT "chars"
120 FOR A= 0TO 128
130 PRINT A;SPC(5); TABLE(A)
160 BPUT# C,TABLE(A)
170 NEXT A
180 CLOSE# C
190 END
```

Listing 1 Translation table generator.

other languages or word-processing ROMs, at least not in the author's experience. An alterantive location for disc users is page 8: 900h to 9B8h, an area normally used for tape buffers. The location of the program is set by lines 10, 20, 50 and 220 in Listing 3a and in Listing 4.

Construction and Installation

The convertor is assembled on a small PCB which sits piggy-back over the site of the interface's original EPROM, which should be removed and replaced with wire links (Fig. 2). Before fitting the convertor, connect the links from pins 2, 3, 4, 5, 6, 7 and 8 to pins 16, 15, 14, 13, 11, 10 and 9, respectively, on the EPROM socket. Three connections (D7, 0V and +5V) are made from the convertor to the interface, fitting pins 1, 12 and 24 in the EPROM socket. If these are made in thick gauge wire, they serve to anchor the boards together sufficiently (Fig. 2).

Connection to the micro is by means of 26-way ribbon cable, with an insulation displacement connector at the micro, which plugs into the parallel printer socket on the underside of the computer. IDC connectors are the answer to many a constructor's prayer as a means of connecting so many wires at once: they can be bought ready assembled, but are simplicity itself to make up. Just position the cable over the plug, matching wires with contact points, fit the plastic cover plate, taking care to line it up, and tap gently with a hammer. With luck all connections are made at once and it then only remains to fit the strain relief clamp over the cable.

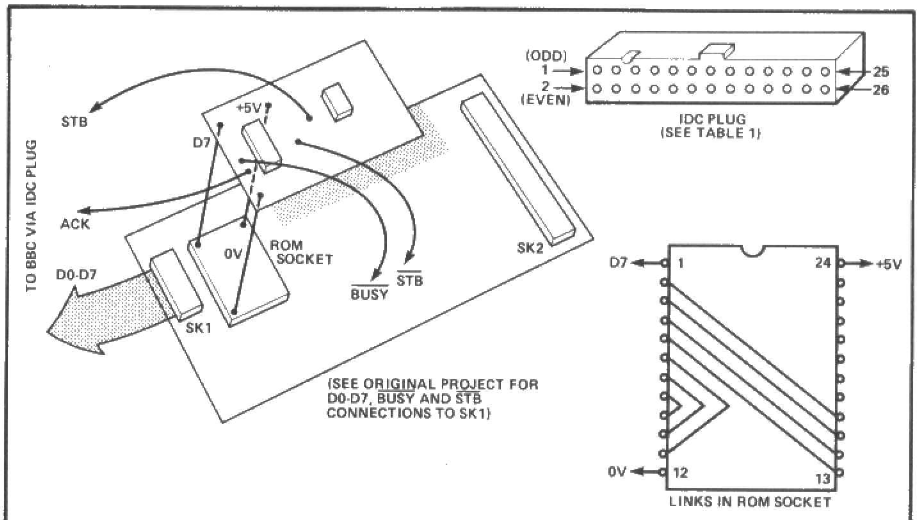


Fig. 4 Connections between boards, on original ROM socket and to IDC plug.

LOC	CONT	CH	LOC	CONT	CH	LOC	CONT	CH	LOC	CONT
0	16		32	1	@	64	10	`	96	68
1	16	!	33	71	A	65	87	a	97	23
2	16	"	34	103	B	66	93	b	98	29
3	16	£	35	90	C	67	94	c	99	30
4	16	$	36	102	D	68	86	d	100	22
5	16	%	37	69	E	69	78	e	101	14
6	16	&	38	101	F	70	118	f	102	54
7	16	'	39	68	G	71	85	g	103	21
8	16	(	40	100	H	72	117	h	104	53
9	16	)	41	67	I	73	108	i	105	44
10	137	*	42	82	J	74	84	j	106	20
11	16	+	43	115	K	75	116	k	107	52
12	16	,	44	60	L	76	83	l	108	19
13	137	-	45	2	M	77	92	m	109	28
14	16	.	46	27	N	78	125	n	110	61
15	16	/	47	59	O	79	75	o	111	11
16	16	0	48	35	P	80	107	p	112	43
17	16	1	49	7	Q	81	79	q	113	15
18	16	2	50	39	R	82	110	r	114	46
19	16	3	51	6	S	83	119	s	115	55
20	16	4	52	38	T	84	77	t	116	13
21	16	5	53	5	U	85	76	u	117	12
22	16	6	54	37	V	86	126	v	118	62
23	16	7	55	4	W	87	111	w	119	47
24	16	8	56	36	X	88	127	x	120	63
25	16	9	57	3	Y	89	109	y	121	45
26	16	:	58	18	Z	90	95	z	122	31
27	16	;	59	51	[	91	202	{	123	1
28	16	<	60	196	\	92	1	¦	124	187
29	16	=	61	99	]	93	138	}	125	1
30	16	>	62	194	^	94	1	~	126	1
31	16	?	63	123	_	95	66		127	16

Listing 2 Decimal data for translation table.

```
 10 store = &0CB7
 20 storey = &0CB8
 30 OSBYTE = &FFF4
 40 FOR opt%=0 TO 3 STEP 3
 50 P%=&0C81
 60  [
 70 OPT opt%
 80 PHP
 90 STY storey
100 CPX #&03
110 BNE exit
120 STA store
130 LDA #&80
140 LDX #&FC
150 LDY #&FF
160 JSR OSBYTE
170 CPX #&00
180 BEQ escape
190 LDA store
200 AND #&7F
210 TAX
220 LDA &0C00,X
230 LDX #&03
240 .exit PLP
250 LDY storey
260 JMP &E4B3
270 .escape LDA store
280 LDX #&03
290 JMP exit
300  ]
310 NEXT opt%
320 END
```

Listing 3a BASIC program to assemble translation program.

```
0C81           OPT opt%
0C81 08        PHP
0C82 8C B8 0C  STY storey
0C85 E0 03     CPX #&03
0C87 D0 1B     BNE exit
0C89 8D B7 0C  STA store
0C8C A9 80     LDA #&80
0C8E A2 FC     LDX #&FC
0C90 A0 FF     LDY #&FF
0C92 20 F4 FF  JSR OSBYTE
0C95 E0 00     CPX #&00
0C97 F0 12     BEQ escape
0C99 AD B7 0C  LDA store
0C9C 29 7F     AND #&7F
0C9E AA        TAX
0C9F BD 00 0C  LDA &0C00,X
0CA2 A2 03   . LDX #&03
0CA4 28        .exit PLP
0CA5 AC B8 0C  LDY storey
0CA8 4C B3 E4  JMP &E4B3
0CAB AD B7 0C  .escape LDA store
0CAE A2 03     LDX #&03
0CB0 4C A4 0C  JMP exit
```

Listing 3b Runtime display of assembly program.

At the interface end, you can use a D-type plug and socket but with a little care and patience it's perfectly possible to do without this, and solder wires from the ribbon cable directly into the PCBs.

A reminder that BUSY and STROBE are connected from convertor to interface, while ACK and STROBE run from convertor to micro. Connection details (courtesy of the BBC handbook) are shown in Table 1 and the IDC plug pin numbering can be seen in Fig. 2.

Signal	IDC wire no.
STROBE	1
DO	3
D1	5
D7	7
D3	9
D4	11
D5	13
D6	15
D7	17
ACK	19
Ground	20 (and all even nos.)

Table 1 IDC plug connection details.

Further Developments

The one drawback to using D7 to signal carriage return is that the original design reserved this line to denote the alternative character set which is needed for certain ASCII characters (assuming you have that daisy-wheel fitted). This can still be done, but the penalty is a 2s delay every time such a character is printed. Further software could make use of the delay when back-spaces are output, for underlining. The keyboard code for a back-space is 25 (decimal) and this could be assigned to one of the unused ASCII codes and built into a specialised printer driver routine from the word-processor.

```
*BUILD !BOOT (return), then type:
     *LOAD chars 0C00
     *LOAD mc 0C81
     ?&22A=&81: ?&22B=&0C
     *WORD
     (ESCAPE)
     *OPT4,3 (return)
```

Listing 4 Program to assemble !BOOT file to load and run translation program from disc.

Further details of Operating System routines in the BBC Micro can be found in 'The Advanced User Guide For The BBC Micro', by Bray, Dickens and Holmes — published by the Cambridge Microcomputer Centre at £12.95.

ETI

(X) NOTE:- IC8 6117
USE 6116 INSTEAD
IDENTICAL PIN OUT

EPROM EMULATOR

At long last, this much-delayed project hits the pages of ETI. Design by new project editor, Paul Chappell.

The EPROM emulator described here is primarily intended to assist with the preparation of programs for the '6802 Evaluation board' (ETI, May 1985), although it can equally well be used with any other system using 2716 EPROMs. The circuit uses a bare minimum of parts and the cost and construction time should be similarly minimal.

In use, a computer is connected to port A, and port B goes to the EPROM socket of the circuit that will run the program. With S1 in the 'program' position, the program to be tested is loaded from the computer into the 6117 memory IC. SW1 is then set to the 'EPROM' position and the program is run. If the program fails to perform as intended, SW1 is returned to the 'program' position and modifications are made from the computer. The new program can then be run, and so the process continues until the program does what is required of it.

Construction

The connections on the right hand side of the board are

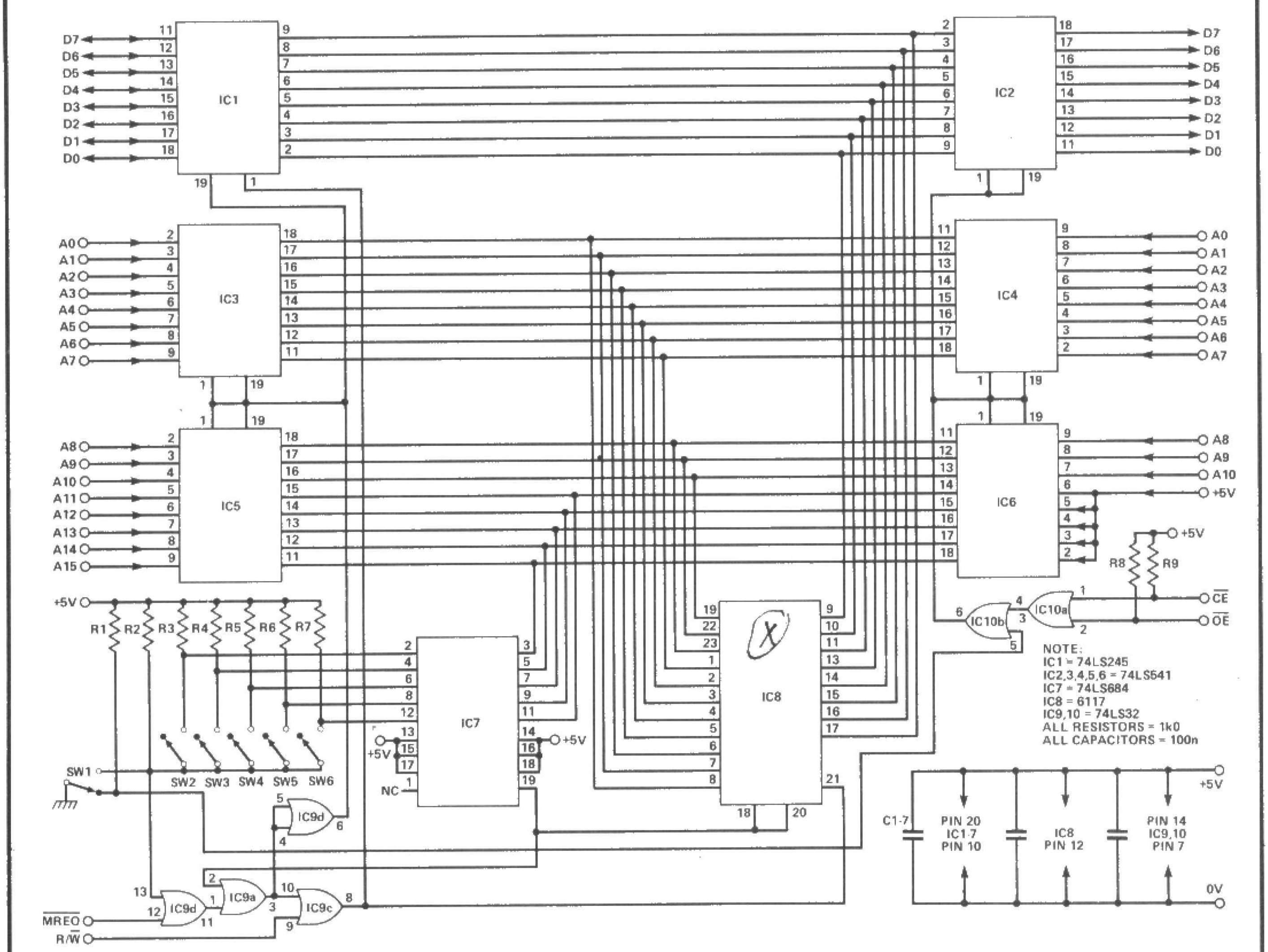


Fig. 1 Circuit diagram of the emulator

arranged so that a length of 24-way ribbon cable can be connected to a 24-pin DIL header to plug into the EPROM socket of the host system. If an insulation displacement type of header is used, the connections will automatically be in the right order; otherwise, wires should be soldered to alternate sides of the header, with the bottom connection to pin 24, the next to pin 1, next pin 23, then 2, and so on.

A double sided board is used, and where possible through connections have been made via component leads, so check the top (component side) of the board carefully to make sure that any pads around component leads have been soldered. Positions where a wire through-link is required are marked with a '*' on the component overlay. The memory IC can be socketed but the less expensive ICs should be soldered directly to the board to make it easier to solder the top side of the lead where this is required.

HOW IT WORKS

Switches SW2 to SW6 allow the emulator to be placed at any convenient point within the computer's memory map. If they are all set to 0, the emulator memory will represent the first 2K of the computer's memory, and each binary code increment will shift it upwards by 2K. Suppose your computer has 16K of memory and you would like the emulator board to run from 16K to 18K. You want to shift the emulator location upwards by 16K, so the switches would have to be set to 00100, because this is the binary for '8', and you want a shift of 8 x 2K. The switch codes are, in fact, compared directly with the upper 5 address lines from the computer by IC7. IC1, IC3 and IC5 allow the computer access to the memory on the emulator board when a valid address and the appropriate control signals are received. The computer then writes to or reads from the emulator memory as if it were an extension of its own memory.

With switch SW1 in the 'EPROM' position, the computer no longer has access to the emulator's memory; instead, IC2, IC4 and IC6 are enabled by CE and OE signals from the host system, which will now have access to the emulator's memory for read operations only — as if it were an EPROM.

PARTS LIST

RESISTORS

R1-9	1k miniature carbon film

CAPACITORS

C1-10	100n disc ceramic

SEMICONDUCTORS

IC1	74LS245
IC2-6	74LS541
IC7	74LS684
IC8	6117
IC9	74LS32

MISCELLANEOUS

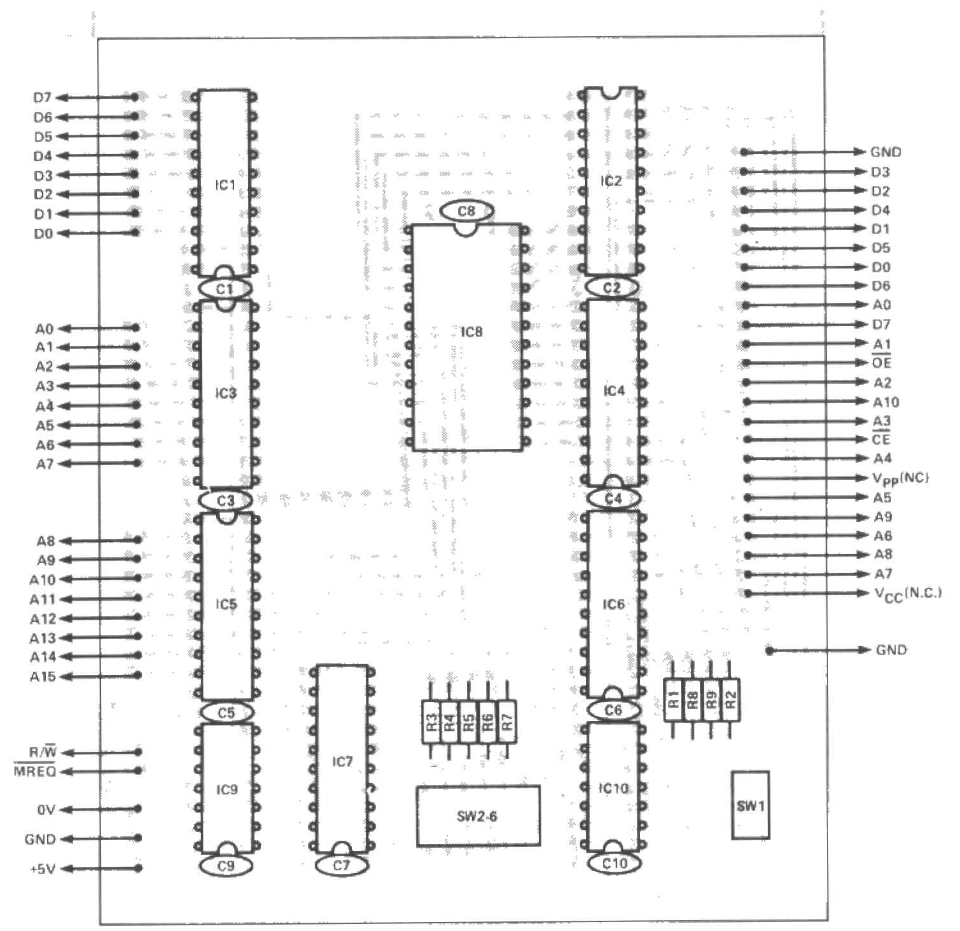
SW1	PCB mounting miniature SPST toggle switch
SW2-6	Six section, SP make DIL switch (one off)

Length of 24-way ribbon cable; 24-way DIL plug; PCB; cable and socket for connection to computer.

BUYLINES

The components for the prototype were all supplied by Watford, who have everything in stock. The 6117 RAM and 74LS684 comparator might prove problematic if sought from other suppliers, but everything else should be easily available. The PCB is supplied by ETI PCB Service.

Fig. 2 Component overlay of the emulator



ETI

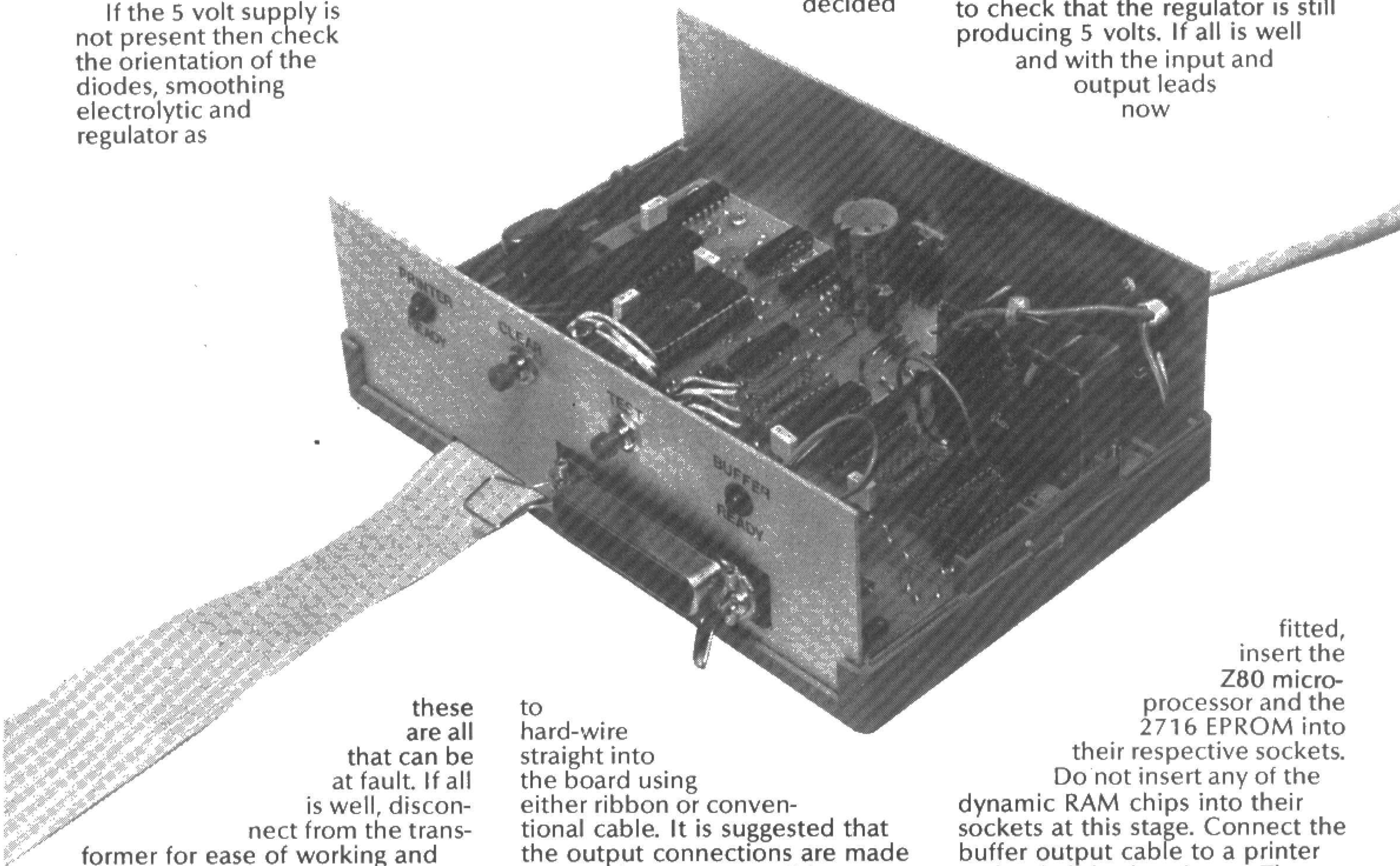
PRINTER BUFFER

Following on from last month's article which covered the design and construction, Nick Sawyer describes the connection, testing and use of the buffer and presents a full listing of the EPROM contents.

It is recommended that the power supply is built and checked before adding anything else that could be damaged by a power supply fault. First solder in diodes D2 and D3, capacitors C3-8 and the 7805 voltage regulator, IC17. When wired up to the transformer and plugged into the mains, this combination should give five volts plus or minus 5% at the output of the regulator.

If the 5 volt supply is not present then check the orientation of the diodes, smoothing electrolytic and regulator as these are all that can be at fault. If all is well, disconnect from the transformer for ease of working and proceed with fitting the other components and sockets to the board.

It has to be decided at this point how the connections to the unit are going to be made. The best method of making the input connection is by mounting a right angle 36 way connector on the PCB. This means that the printer lead you were already using will plug straight into the buffer. As connectors are rather expensive however, it might be decided to hard-wire straight into the board using either ribbon or conventional cable. It is suggested that the output connections are made using either a 26 way ribbon cable soldered direct into the PCB or a 26 way IDC plug and socket. The other end of the cable can be terminated in a 36 way IDC connector ready for connection to the printer. The two LEDs and the two switches are mounted on the front of the box and wired to the relevant points on the printed circuit board.



Testing

It is a good idea at this stage to check that the regulator is still producing 5 volts. If all is well and with the input and output leads now fitted, insert the Z80 microprocessor and the 2716 EPROM into their respective sockets. Do not insert any of the dynamic RAM chips into their sockets at this stage. Connect the buffer output cable to a printer and switch both units on. The 'buffer ready' LED should illuminate after about a second if all is

0000	F3	C3	80	00	00	00	00	00	00	00	00	00	00	00	00	00	0400	33	33	11	00	20	21	C0	04	7E	FE	FF	CA	1E	04	DB	FF
0010	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0410	E6	80	CA	0E	04	7E	12	32	00	30	23	C3	08	04	21	D3
0020	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0420	04	7E	FE	FF	CA	37	04	DB	FF	E6	80	CA	27	04	7E	12
0030	00	00	00	00	00	00	00	00	F3	C3	00	04	00	00	00	00	0430	32	00	30	23	C3	21	04	D9	78	D9	47	FE	3F	3E	31	CA
0040	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0440	4C	04	78	FE	7F	3E	33	CA	4C	04	3E	34	4F	DB	FF	E6
0050	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0450	80	CA	4D	04	79	12	32	00	30	78	FE	3F	3E	36	CA	6B
0060	00	00	00	00	00	00	C3	80	00	00	00	00	00	00	00	00	0460	04	78	FE	7F	3E	32	CA	6B	04	3E	38	4F	DB	FF	E6	80
0070	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0470	CA	6C	04	79	12	32	00	30	DB	FF	E6	80	CA	78	04	3E
0080	31	FF	FF	ED	56	01	00	80	3E	00	02	0A	FE	00	CA	9A	0480	4B	12	32	00	30	DB	FF	E6	80	CA	85	04	3E	0D	12	32
0090	00	D9	C6	3F	0E	80	D9	C3	BB	00	01	00	C0	3E	00	02	0490	00	30	DB	FF	E6	80	CA	92	04	3E	0A	12	32	00	30	C3
00A0	0A	FE	00	CA	AF	00	D9	06	7F	0E	C0	D9	C3	BB	00	01	04A0	00	05	21	E2	04	7E	FE	FF	CA	BD	04	DB	FF	E6	80	CA
00B0	00	00	D9	06	BF	0E	00	D9	21	00	40	36	00	23	7C	BB	04B0	AB	04	7E	32	00	20	32	00	30	23	C3	A5	04	C3	00	01
00C0	C2	BB	00	7D	B9	C2	BB	00	3A	00	10	C3	00	01	00	00	04C0	52	61	6D	20	74	65	73	74	20	73	74	61	72	74	65	64
00D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	04D0	0A	0D	FF	52	61	6D	20	70	72	65	73	65	6E	74	20	3A
00E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	04E0	20	FF	52	61	6D	20	74	65	73	74	20	63	6F	6D	70	6C
00F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	04F0	65	74	65	64	0A	0D	FF	00	00	00	00	00	00	00	00	00
0100	01	00	40	11	00	40	21	00	00	3E	FF	32	00	20	FB	00	0500	21	00	40	7D	84	2F	77	23	C3	B0	05	00	00	00	00	00
0110	F3	C3	80	01	3E	FF	BD	C2	21	01	D9	78	D9	BC	CA	3E	0510	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0120	01	DB	FF	E6	40	CA	3E	01	3A	00	10	02	23	03	3E	00	0520	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0130	B9	C2	3E	01	D9	79	D9	B8	C2	3E	01	01	00	40	7C	B5	0530	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0140	CA	00	01	DB	FF	E6	80	CA	11	01	1A	32	00	20	32	00	0540	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0150	30	2B	13	3E	00	BB	C2	11	01	D9	79	D9	BA	C2	11	01	0550	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0160	11	00	40	C3	11	01	00	00	00	00	00	00	00	00	00	00	0560	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0170	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0570	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0180	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0580	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0190	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	0590	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01A0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	05A0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01B0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	05B0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01C0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	05C0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	05D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	05E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
01F0	00	00	00	00	00	00	00	00	00	00	00	00	00	C3	14	01	05F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0200	30	31	32	33	34	35	36	37	38	39	41	42	43	44	45	46	0600	7C	D9	B9	D9	C2	03	05	7D	FE	00	C2	03	05	11	FF	7F
0210	47	EB	21	A0	02	7E	FE	FF	CA	2D	02	DB	FF	E6	80	CA	0610	1B	C3	80	06	00	00	00	00	00	00	00	00	00	00	00	00
0220	1B	02	7E	32	00	20	32	00	30	23	C3	15	02	7A	0F	0F	0620	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0230	0F	0F	E6	0F	6F	26	02	DB	FF	E6	80	CA	37	02	7E	32	0630	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0240	00	20	32	00	30	7A	E6	0F	6F	DB	FF	E6	80	CA	49	02	0640	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0250	7E	32	00	20	32	00	30	7B	0F	0F	0F	0F	E6	0F	6F	DB	0650	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0260	FF	E6	80	CA	5F	02	7E	32	00	20	32	00	30	7B	E6	0F	0660	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0270	6F	DB	FF	E6	80	CA	71	02	7E	32	00	20	32	00	30	DB	0670	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0280	FF	E6	80	CA	7F	02	3E	0D	32	00	20	32	60	30	DB	FF	0680	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0290	E6	80	CA	8E	02	3E	0A	32	00	20	32	00	30	C3	00	03	0690	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
02A0	52	41	4D	20	66	61	69	6C	20	61	74	20	6C	6F	63	61	06A0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
02B0	74	69	6F	6E	20	3A	20	FF	00	00	00	00	00	00	00	00	06B0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
02C0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	06C0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
02D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	06D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
02E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	06E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
02F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	06F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0300	21	CE	03	7E	FE	FF	CA	1B	03	DB	FF	E6	80	CA	09	03	0700	7A	B3	C2	10	06	21	00	40	C3	B0	07	7E	2F	94	BD	CA
0310	7E	32	00	20	32	00	30	23	C3	03	03	7B	82	0F	0F	0F	0710	17	07	84	2F	C3	10	02	23	7C	D9	B9	D9	C2	80	07	7D
0320	0F	2F	E6	0F	26	02	6F	DB	FF	E6	80	CA	27	03	7E	32	0720	FE	00	C2	B0	07	C3	A2	04	00	00	00	00	00	00	00	00
0330	00	20	32	00	30	7B	82	2F	E6	0F	6F	DB	FF	E6	80	CA	0730	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0340	3B	03	7E	32	00	20	32	00	30	DB	FF	E6	80	CA	49	03	0740	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0350	3E	0D	32	00	20	32	00	30	DB	FF	E6	80	CA	58	03	3E	0750	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0360	0A	32	00	20	32	00	30	21	DF	03	7E	FE	FF	CA	83	03	0760	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0370	DB	FF	E6	80	CA	70	03	7E	32	00	20	32	00	30	23	C3	0770	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0380	6A	03	7B	0F	0F	0F	0F	E6	0F	26	02	6F	DB	FF	E6	80	0780	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0390	CA	8D	03	7E	32	00	20	32	00	30	7B	E6	0F	6F	DB	FF	0790	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
03A0	E6	80	CA	9F	03	7E	32	00	20	32	00	30	DB	FF	E6	80	07A0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
03B0	CA	AD	03	3E	0D	32	00	20	32	00	30	DB	FF	E6	80	CA	07B0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
03C0	BC	03	3E	0A	32	00	20	32	00	30	C3	00	01	44	61	74	07C0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
03D0	61	20	77	72	69	74	74	65	6E	20	20	3A	20	FF	44	61	07D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
03E0	74	61	20	72	65	74	75	72	6E	65	64	20	3A	20	FF	00	07E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
03F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	07F0	00	00	00	00	00	00	00	00	00	00	00	00	00	C3	0B	07

Table 1 Full listing of the software which must be programmed into the 2716 EPROM.

well with the buffer, and the 'printer ready' LED should light and extinguish as the printer is put on-line/off-line.

If all is well press the test button. The printer should produce "RAM Test Started" followed immediately by "RAM Present : 16K" and ten seconds later by "RAM Fail at Location 4000". This shows all is well, that the unit is functioning and that those expensive dynamic RAM chips can now be used. The first pair of RAMs is inserted (observing normal MOS precautions) in positions IC11 and IC14, the next pair in IC10 and IC13 and the last pair in IC9 and IC12. Take great care that these devices are the right way around in their holders. The buffer will work with either 16, 32 or 48K of RAM provided the RAM chips are installed in the right sockets.

Having installed all the RAM you think necessary, switch every-

thing back on and repeat the test as above. The results should be the same except that the "RAM present" figure should reflect the amount of RAM that you have installed, and after ten seconds the printer should produce "Ram Test Passed".

The buffer is now ready to use. Plug in the lead from your computer and try LLIST on a fairly long program. The computer should come back READY within a few seconds, and the printer should carry on printing until it is finished — with no errors of course!

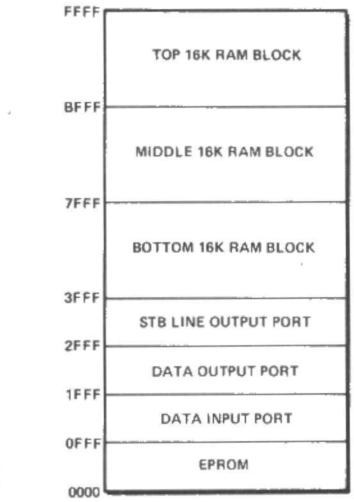


Fig. 4 Map of the memory locations.

Faultfinding

Having built the buffer, if you are unfortunate enough to find that nothing happens when you switch on, check the obvious first. Is the printer on-line? If it is then the 'printer ready' LED should be glowing, if it is not, check carefully the output lead from the buffer to the printer.

Next check the 5 volt supply from the regulator. If it has dropped from five to only one or two volts, then it is likely that there is either a short circuit between two solder joints or that a component has been soldered in the wrong way round. If this is the case a hot component will result and can easily be tracked down by the burning smell. If the 5 volt supply is still all right, then it is more likely that you have missed a solder joint out. Check all the through board connections for continuity, and check especially the output wiring from the buffer to the printer plug.

If all still appears well but the buffer fails to function the services of an oscilloscope will ideally be required. Check first for a 2 MHz clock signal on pin 6 of the Z80, then check the operation of each address, data and control line. If they have a varying signal on them then all is well, otherwise suspect a short circuit at some point.

In Use

The use of the printer buffer is absolutely straight forward as it is completely transparent to the user and his computer. Merely leave the unit connected to the printer, and power it up whenever the printer is switched on. Any data sent from the computer will then be buffered and passed on at a speed suitable for your printer, leaving the computer free for use.

ETI

UNIVERSAL EPROM PROGRAMMER MKII

This hex dump spells a fully operational EPROM Programmer — and you can't byte that. Gordon Bennett performed the magic.

Last month, lack of space obliged us to hold over the software listings for the EPROM Programmer. This month we remedy that omission with a complete hex dump of the Universal EPROM Programmer software. Unfortunately, space reasons forbid the publication of the complete disassembled listings — which runs to some 26 pages of print-out.

The hex dump provides everything you need in order to enter the code to run the programmer. Notes on the various locations involved can be found in last month's introductory article and below. If anyone should require the disassembled listing, for the purposes of modification or out of simple interest, we can provide a photocopy at a price of £3. Please send a cheque, made out to ASP Ltd., to ETI, Dept. UEP, 1 Golden Square, London W1R 3AB, and enclose a large stamped addressed envelope. The author will provide a ready programmed EPROM plus listing for £10.00 or a tape including source and object code (for use with the TUG two pass/assembler editor) for £5.00. Please write to 187 Beaulieu Gardens, Blackwater, Camberley, Surrey GU17 0LF. Note that this address is different from the one published last month, and is the correct address. Please allow 28 days for delivery on any of these items.

The following hex dump was performed using the DUMP command in the EPROM Programmer software. The first address on a line is the absolute address in memory, the second is the offset address from the current Base selected. Then there are 16 bytes of data and the final number is the checksum computed from that line of data. With reference to last month's notes, the screen clear routine is located at EFEC h to EFFF h, inclusive. It may be removed for the addition of extra facilities in the program. It is called twice, by the command JSR CLRSCRN (the hex bytes 20 EC EF), at locations E9CF h and EA23 h (the header and the help routines). Locations E861 h through E8C8 h contain the type numbers of the EPROMs supported by the software. Length parameters are contained in the locations E8C9 h through E8D5 h. Messages used in the programme are contained in locations E8F6 h through E9C h. The table used to set up PIO ports for the EPROMs supported are contained in locations E806 h through E860 h. These tables could be altered to support different EPROMs, but — once again — close study of the disassembled listing is recommended.

The hex dump from E800 h to EFFF h.

```
E800 0000  4C D8 E9 4C E7 E9 3C 3C 3C 3C 3C 3C 34 34 34 34  0661
E810 0010  34 34 34 98 98 98 90 90 98 92 92 90 92 92 90 90  0814
E820 0020  18 18 18 08 08 18 10 10 10 10 10 10 00 88 88 88  0268
E830 0030  85 A5 88 22 C2 00 22 C2 C1 C5 01 01 01 01 01 10  0515
E840 0040  02 02 10 02 02 01 01 06 06 06 06 06 0A 06 06 0A  0058
E850 0050  06 06 06 06 01 01 01 01 01 00 01 01 00 01 01 01  0022
E860 0060  01 32 37 35 38 20 20 20 20 32 37 31 36 20 20 20  0287
E870 0070  20 32 35 31 36 20 20 20 20 32 37 33 32 20 20 20  029C
E880 0080  20 32 37 33 32 41 20 20 20 32 35 33 32 20 20 20  02BB
E890 0090  20 32 37 36 34 20 20 20 20 32 37 36 34 41 20 20  02C7
E8A0 00A0  20 32 35 36 34 20 20 20 20 32 37 31 32 38 20 20  02B5
E8B0 00B0  20 32 37 31 32 38 41 20 20 32 37 32 35 36 20 20  02EB
```

E8C0	00C0	20	32	37	35	31	32	20	20	20	03	07	07	0F	0F	0F	1F	01DE
E8D0	00D0	1F	1F	3F	3F	7F	FF	48	51	54	52	56	46	53	4E	44	42	053C
E8E0	00E0	23	EA	87	EB	8D	EB	28	ED	DF	EB	88	ED	84	ED	26	EB	0ACD
E8F0	00F0	38	EC	68	EB	EA	E9	45	50	52	4F	4D	20	54	59	50	45	072F
E900	0100	00	42	41	53	45	20	41	44	44	52	45	53	53	20	28	48	03D1
E910	0110	45	58	29	00	45	50	52	4F	4D	20	50	52	4F	47	52	41	0434
E920	0120	4D	4D	45	44	2C	20	56	45	52	49	46	59	49	4E	47	2E	0450
E930	0130	00	45	50	52	4F	4D	20	43	48	45	43	4B	20	46	49	4E	03FE
E940	0140	49	53	48	45	44	00	45	50	52	4F	4D	20	56	45	52	49	0446
E950	0150	46	49	45	44	20	4F	4B	00	45	50	52	4F	4D	20	45	52	040C
E960	0160	41	53	45	44	20	4F	4B	00	45	50	52	4F	4D	20	53	49	0416
E970	0170	5A	45	20	45	58	43	45	45	44	45	44	00	20	20	20	20	0376
E980	0180	20	20	20	00	45	52	52	4F	52	20	40	20	24	00	20	4D	02FB
E990	0190	45	4D	2E	3D	00	20	45	50	52	4F	4D	3D	00	20	42	41	0380
E9A0	01A0	53	45	20	3D	20	24	00	0D	20	20	20	2D	20	45	50	52	02DA
E9B0	01B0	4F	4D	20	55	54	49	4C	49	54	49	45	53	20	56	33	2E	044F
E9C0	01C0	37	35	2D	0D	0D	0D	45	6E	74	65	72	3A	2D	0D	00	20	0352
E9D0	01D0	EC	EF	A0	B1	20	6B	EF	60	20	C2	EA	20	DF	EA	20	CF	09AA
E9E0	01E0	E9	20	26	EB	20	68	EB	20	23	EA	EA	20	DF	EA	20	14	07C1
E9F0	01F0	EB	20	1D	F8	A5	01	48	20	0E	F8	68	A2	00	DD	D6	E8	07D9
EA00	0200	F0	08	E8	E0	0A	D0	F6	4C	EB	E9	8A	0A	AA	BD	E0	E8	0A73
EA10	0210	85	5C	E8	BD	E0	E8	85	5D	AD	F5	E8	48	AD	F4	E8	48	0AD3
EA20	0220	6C	5C	00	20	EC	EF	20	0C	F8	A0	9F	20	6B	EF	A9	00	0749
EA30	0230	85	53	A5	52	0A	0A	0A	AA	BD	61	E8	20	0E	F8	E8	E6	0791
EA40	0240	53	A5	53	C9	08	90	F1	A0	A7	20	6B	EF	A5	4B	20	1A	0788
EA50	0250	F8	A5	4A	20	1A	F8	A2	00	BD	67	EA	C9	00	F0	07	20	07A9
EA60	0260	0E	F8	E8	4C	58	EA	60	0D	0D	28	48	29	65	6C	70	0D	05DD
EA70	0270	28	51	29	75	69	74	0D	28	54	29	65	73	74	0D	28	52	0479
EA80	0280	29	65	61	64	0D	28	56	29	65	72	69	66	79	0D	28	46	04A1
EA90	0290	29	61	73	74	20	50	72	6F	67	2E	0D	28	53	29	6C	6F	04E3
EAA0	02A0	77	20	50	72	6F	67	2E	0D	28	44	29	75	6D	70	0D	28	0486
EAB0	02B0	4E	29	65	77	20	74	79	70	65	0D	28	42	29	61	73	65	050E
EAC0	02C0	0D	00	A9	30	8D	21	BC	8D	23	BC	8D	27	BC	8D	2B	BC	06A0
EAD0	02D0	A9	FF	8D	20	BC	8D	22	BC	8D	26	BC	8D	2A	BC	60	A9	0867
EAE0	02E0	04	8D	27	BC	8D	2B	BC	8D	2A	BC	A9	90	8D	26	BC	A9	07AC
EAF0	02F0	34	8D	21	BC	8D	23	BC	A9	00	8D	25	BC	8D	20	BC	8D	0717
EB00	0300	22	BC	A9	FF	8D	24	BC	A9	04	8D	25	BC	A9	00	8D	24	0768
EB10	0310	BC	85	48	60	20	0C	F8	A9	3E	20	0E	F8	60	20	0C	F8	069E
EB20	0320	A9	24	20	0E	F8	60	20	0C	F8	A0	00	20	6B	EF	20	14	05C5
EB30	0330	EB	20	C4	EF	20	E6	EF	A2	00	86	52	A0	01	B1	0A	C9	0852
EB40	0340	20	F0	24	DD	61	E8	D0	05	C8	E8	4C	3D	EB	E6	52	A5	0930
EB50	0350	52	0A	0A	0A	C9	68	B0	04	AA	4C	3B	EB	20	0C	F8	A9	063E
EB60	0360	3F	20	0E	F8	4C	2E	EB	60	20	0C	F8	A0	0B	20	6B	EF	0673
EB70	0370	20	1D	EB	20	C4	EF	A0	00	20	17	F8	A5	13	85	4A	A5	06F6
EB80	0380	14	85	4B	20	0C	F8	60	20	0C	F8	4C	20	F8	A9	00	85	061E
EB90	0390	53	85	4C	85	4D	A9	FF	85	4E	A6	52	BD	C9	E8	E0	0C	08C3
EBA0	03A0	D0	0B	A9	7F	20	AD	EB	A9	80	85	4D	A9	FF	85	4F	20	0852
EBB0	03B0	CC	EC	A9	01	85	51	20	35	ED	20	44	EE	D0	06	A0	62	07A4
EBC0	03C0	20	6B	EF	60	A0	8E	20	6B	EF	20	7A	EF	A0	9F	20	6B	07D5
EBD0	03D0	EF	20	98	EF	20	A3	EF	D0	03	20	AA	EF	4C	B6	EB	20	08E1
EBE0	03E0	99	EC	20	CC	EC	20	59	EF	A9	80	85	51	A9	00	85	47	0839
EBF0	03F0	85	53	20	35	ED	20	44	EE	D0	13	20	DF	EA	A5	47	F0	0814
EC00	0400	06	A0	3B	20	6B	EF	60	A0	50	20	6B	EF	60	20	1F	EC	06B0
EC10	0410	A9	01	85	47	20	A3	EF	D0	03	20	AA	EF	4C	F2	EB	A0	087D
EC20	0420	8E	20	6B	EF	20	7A	EF	A0	98	20	6B	EF	20	90	EF	A0	0882
EC30	0430	9F	20	6B	EF	20	98	EF	60	20	99	EC	20	CC	EC	20	0C	07C9
EC40	0440	F8	A9	00	85	53	85	5E	85	5F	20	32	EE	F0	25	20	85	073A
EC50	0450	EF	20	E6	EF	20	7A	EF	20	E6	EF	20	E6	EF	A2	00	A1	099A

EC60	0460	45	48	20	8D	EC	68	20	1A	F8	20	86	EC	F0	06	20	32	069A
EC70	0470	EE	D0	E7	60	A0	8B	20	6B	EF	A5	5F	20	1A	F8	A5	5E	08E3
EC80	0480	20	1A	F8	4C	3E	EC	E6	53	A5	53	C9	10	60	18	65	5E	06ED
EC90	0490	85	5E	A5	5F	69	00	85	5F	60	20	C4	EF	A0	02	20	17	0640
ECA0	04A0	F8	A5	13	85	4C	A5	14	85	4D	20	17	F8	A5	13	85	4E	06C6
ECB0	04B0	A5	14	85	4F	C5	4D	90	09	D0	06	A5	4E	C5	4C	90	01	06A3
ECC0	04C0	60	20	0C	F8	A9	3F	20	0E	F8	4C	C1	EF	38	A5	4C	E9	07A0
ECD0	04D0	01	85	55	A5	4D	E9	00	85	56	18	A5	4E	69	01	85	57	05E2
ECE0	04E0	A5	4F	69	00	85	58	18	A5	4A	65	55	85	45	A5	4B	65	061A
ECF0	04F0	56	85	46	20	0C	F8	60	A6	52	BD	06	E8	8D	23	BC	A9	075D
ED00	0500	00	8D	20	BC	A9	04	8D	25	BC	BD	13	E8	8D	26	BC	A9	0754
ED10	0510	12	8D	2A	BC	60	AD	2A	BC	49	10	8D	2A	BC	20	4F	EE	06A1
ED20	0520	AD	24	BC	85	50	A2	00	60	20	99	EC	20	CC	EC	20	59	075A
ED30	0530	EF	A9	00	85	51	A2	00	20	55	EE	20	F7	EC	20	4F	EE	07D3
ED40	0540	20	32	EE	F0	1F	20	D1	ED	20	15	ED	A4	51	F0	10	30	0774
ED50	0550	07	C9	FF	F0	E5	4C	64	ED	C1	45	F0	DE	4C	64	ED	81	0A33
ED60	0560	45	4C	3A	ED	60	A6	52	BD	06	E8	8D	23	BC	A9	00	8D	075D
ED70	0570	20	BC	A9	04	8D	25	BC	BD	20	E8	8D	2A	BC	BD	2D	E8	0801
ED80	0580	8D	26	BC	60	A9	01	85	48	20	99	EC	20	CC	EC	20	59	073C
ED90	0590	EF	A5	52	C9	06	90	07	A5	48	D0	03	4C	7E	EE	A2	FF	0865
EDA0	05A0	20	55	EE	20	65	ED	20	21	EF	20	4F	EE	20	32	EE	F0	0792
EDB0	05B0	1D	20	D1	ED	A2	00	A1	45	8D	24	BC	20	63	EE	A0	1D	071E
EDC0	05C0	A2	FF	CA	D0	FD	88	D0	FA	20	63	EE	4C	A3	ED	4C	F5	0B18
EDD0	05D0	EE	A5	55	8D	22	BC	BD	54	E8	F0	08	A5	56	8D	20	BC	08A8
EDE0	05E0	4C	07	EE	AD	20	BC	05	59	8D	20	BC	A5	56	29	10	F0	06B5
EDF0	05F0	08	AD	20	BC	09	08	8D	20	BC	A5	56	29	08	F0	08	AD	05DC
EE00	0600	26	BC	09	01	8D	26	BC	A5	56	29	20	F0	08	AD	23	BC	0623
EE10	0610	09	08	8D	23	BC	A5	56	29	40	F0	08	AD	26	BC	09	02	0573
EE20	0620	8D	26	BC	A5	56	29	80	F0	08	AD	20	BC	09	80	8D	20	06CA
EE30	0630	BC	60	E6	45	D0	02	E6	46	E6	55	D0	02	E6	56	A5	56	0889
EE40	0640	29	E7	85	59	A5	55	C5	57	D0	04	A5	56	C5	58	60	A0	07F0
EE50	0650	18	88	D0	FD	60	A9	00	8D	25	BC	8E	24	BC	A9	04	8D	078C
EE60	0660	25	BC	60	A6	52	BC	47	E8	B9	20	BC	5D	3A	E8	99	20	07F1
EE70	0670	BC	60	A2	FF	20	55	EE	20	65	ED	20	19	EF	60	A2	00	07BC
EE80	0680	86	5A	E8	86	5B	20	32	EE	20	44	EE	F0	68	20	72	EE	0813
EE90	0690	20	4F	EE	20	D1	ED	A2	00	A1	45	8D	24	BC	20	08	EF	0747
EEA0	06A0	A6	5A	E8	86	5A	A6	52	BD	D9	EF	C5	5A	F0	05	20	42	08BB
EEB0	06B0	EF	D0	DA	20	72	EE	20	4F	EE	20	D1	ED	A5	5A	0A	0A	0867
EEC0	06C0	A8	A6	52	E0	0C	D0	05	A0	02	4C	D8	EE	BD	D9	EF	C9	0963
EED0	06D0	0F	F0	05	98	38	E5	5A	A8	84	5B	20	08	EF	A6	52	BD	0766
EEE0	06E0	D9	EF	C5	5A	D0	98	20	42	EF	F0	93	20	39	EF	20	DF	096A
EEF0	06F0	EA	20	1F	EC	60	20	39	EF	AD	2A	BC	29	12	8D	2A	BC	06FE
EF00	0700	A0	1E	20	6B	EF	4C	E2	EB	20	63	EE	A4	5B	A2	90	CA	08BD
EF10	0710	D0	FD	88	D0	F8	20	63	EE	60	AD	26	BC	29	7F	8D	26	08D8
EF20	0720	BC	A5	52	C9	0C	F0	09	AD	2A	BC	09	1B	8D	2A	BC	60	070B
EF30	0730	AD	2A	BC	09	1A	8D	2A	BC	60	AD	26	BC	09	80	8D	26	0654
EF40	0740	BC	60	A2	00	20	55	EE	20	F7	EC	20	39	EF	20	4F	EE	07C9
EF50	0750	20	D1	ED	20	15	ED	C1	45	60	A6	52	BD	C9	E8	C5	4F	08E0
EF60	0760	B0	08	A0	72	20	6B	EF	4C	C1	EF	60	B9	F6	E8	C9	00	0900
EF70	0770	F0	07	20	0E	F8	C8	4C	6B	EF	60	A5	56	20	1A	F8	A5	07BD
EF80	0780	55	20	1A	F8	60	A5	46	20	1A	F8	A5	45	20	1A	F8	60	0680
EF90	0790	A0	00	B1	45	20	1A	F8	60	A0	00	A5	50	20	1A	F8	20	060F
EFA0	07A0	0C	F8	60	E6	53	A5	53	C9	0E	60	20	1D	F8	A5	01	C9	0770
EFB0	07B0	20	F0	0E	C9	0D	D0	F3	A9	00	85	53	20	0C	F8	60	68	0724
EFC0	07C0	68	68	68	60	A2	00	20	1D	F8	E8	A5	01	C9	20	F0	EF	07C5
EFD0	07D0	90	06	20	0E	F8	4C	C6	EF	60	00	00	00	00	00	00	0F	042C
EFE0	07E0	19	0F	0F	19	19	19	A9	20	20	0E	F8	60	A0	00	A9	20	043A
EFF0	07F0	99	00	02	99	00	03	C8	D0	F7	84	0A	A9	02	85	0B	60	05EF

ETI

TECH TIPS

BCD To Binary Conversion

A.J. Holme
Warrington

The following circuit converts two binary-coded decimal digits into seven-bit binary form. The circuit was originally designed to produce a binary output from two BCD encoded thumbwheel switches. The ten digit bits are labelled T0 - T3 and the units digit bits are labelled U0 - U3. The encoding into binary bits uses two 7483 4-bit binary full adders with fast carry. It may be understood by considering the following sum:

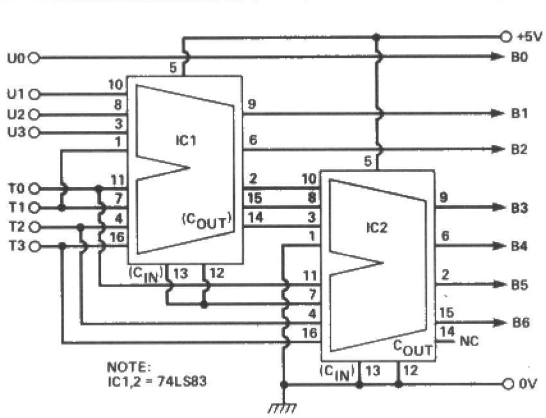
```
      T3 T2 T1 T0 0  (2 x tens)
T3 T2 T1 T0 0 0 0    (8 x tens)
+        U3 U2 U1 U0 (units)
-------------------------------
B6 B5 B4 B3 B2 B1 B0 (binary)
```

For example, the BCD representation of 94 is 1001 0100 (that is, a '9' followed by a '4'). Filling in the above sum, we get:

```
    1 0 0 1 0
1 0 0 1 0 0 0
+     0 1 0 0
-------------
1 0 1 1 1 1 0
```

which is the binary representation of 94.

The two 7483s are configured so that all the relevant bits are added and the binary sum output in the appropriately labelled position. The 74283 could be used — it is functionally identical but has a somewhat more logical pin-out.



Two Utilities for ETI Spectrum/ Centronics Interface

P.H. Sheather
Cranleigh
Surrey

Two programmes are presented here for the Spectrum Interface (ETI, December 1984). The first produces a printed listing of any BASIC programme between designated line numbers. Anyone who has significant experience of programme development and debugging will know that it is invaluable to be able to work on a printed listing rather than the VDU.

The second is a routine intended for use with graphics packages and enables the screen contents to be reproduced on the printer pixel by pixel.

The programmes are written for a 48K SPECTRUM and an EPSON FX80 printer. All necessary interface and printer initialisation is included.

Both programmes read from the screen buffer. In the first the listing is automatically presented on the screen line by line, and transferred to the printer. In the second the screen display will have already been generated by the user.

Communication of commands or data to the printer is carried out by a handshaking subroutine like that of lines 9942 and 9944 of the BASIC programe, or its machine equivalent.

```
9900 REM BASIC LISTING PROGRAMME
********************************
9902 GO TO 9914
9904 PRINT "BASIC LISTING"
9906 PRINT "..............."''
9908 PRINT "MERGE programme for
listing"''
9910 PRINT "Then use RUN 9900"''
: GO TO 9999
9912 REM Select range of line nu
mbers
9914 LET bas=65234
9916 INPUT "First line number?
";fl
9918 INPUT "Last line number?  "
;ll
9920 LET hb=INT (fl/256)
9922 LET lb=fl-256*hb
9924 POKE bas,lb
9926 POKE (bas+1),hb
9928 LET lline=65236
9930 LET hb=INT (ll/256)
9932 LET lb=ll-256*hb
9934 POKE lline,lb
9936 POKE (lline+1),hb
9938 GO TO 9948
9940 REM Handshaking subroutine
9942 IF IN 63<>0 THEN GO TO 9942
9944 OUT 123,n: RETURN
9946 REM Initialise interface
9948 OUT 255,79: PAUSE 10
9950 OUT 251,15: PAUSE 10
9952 REM Clear print buffer
9954 LET n=27: GO SUB 9942
9956 LET n=64: GO SUB 9942
9958 LET n=24: GO SUB 9942
9960 RANDOMIZE USR 65000
9962 CLS : PRINT AT 11,13;"OK"
9964 GO TO 9999
9966 REM Autoload instructons
9968 CLEAR 64999: PRINT AT 11,13
;"WAIT": LOAD "obj"CODE 65000: R
UN 9904
```

```
FDE8 ED 4B D2 FE 2A D4 FE 7C
FDF0 B8 DA FE FD 7C B8 C2 00
FDF8 FE 7D B9 D2 00 FE C9 00
FE00 3E 02 CD 01 16 CD 6B 0D
FE08 00 3E 02 FD 36 02 00 CD
FE10 30 25 C4 01 16 DF CD 70
FE18 20 38 14 DF FE 3B 28 04
FE20 FE 2C 20 06 E7 CD 82 1C
FE28 18 08 CD E6 1C 18 03 CD
FE30 DE 1C CD EE 1B CD 99 1E
FE38 ED 4B D2 FE 78 E6 3F 67
FE40 69 2B 22 49 5C 23 CD 6E
FE48 19 1E 01 CD 55 18 23 7E
FE50 32 D2 FE 2B 7E 32 D3 FE
FE58 3E 7F D7 00 3E 00 32 D6
FE60 FE 3A D6 FE 4F 0C 79 32
FE68 D6 FE 3E 00 32 D7 FE 3A
FE70 D7 FE 47 04 78 32 D7 FE
FE78 3A D6 FE 4F 00 0D 05 CD
FE80 38 25 CD F1 2B 57 00 FE
FE88 7F 20 0A 3A D7 FE FE 01
FE90 20 36 18 3A 00 5A D7 FE
FE98 FE 01 20 18 06 0A 3E 20
FEA0 CD A8 FE 10 F9 18 0D 00
FEA8 5F DB 3F FE 00 20 FA 7B
FEB0 D3 7B C9 00 7A CD A8 FE
FEB8 00 3A D7 FE FE 20 20 AF
FEC0 3E 0A CD A8 FE 18 9A 00
FEC8 3E 0A CD A8 FE 00 C3 E8
FED0 FD 00 00 00 FF FF 00 00
```

```
FDE8 3E 4F D3 FF 06 00 0E 0A
FDF0 CD 3D 1F 3E 0F D3 FB 06
FDF8 00 0E 0A CD 3D 1F 3E 1B
FE00 CD 6D FE 3E 40 CD 6D FE
FE08 3E 1B CD 6D FE 16 B0 3E
FE10 1B CD 6D FE 3E 41 CD 6D
FE18 FE 3E 08 CD 6D FE 3E 0A
FE20 CD 6D FE 3E 1B CD 6D FE
FE28 3E 2A CD 6D FE 3E 05 CD
FE30 6D FE 3E 00 CD 6D FE 3E
FE38 01 CD 6D FE 1E 00 26 00
FE40 2E 01 7A 95 47 4B D5 E5
FE48 CD CE 22 CD 94 1E E1 D1
FE50 CB 04 B4 67 2C 7D FE 09
FE58 20 E8 7C CD 6D FE 1C 7B
FE60 FE 00 20 DA 7A D6 08 57
FE68 FE 00 20 A3 C9 47 DB 3F
FE70 FE 00 20 FA 78 D3 7B C9
```

Clockwise from above: the BASIC listing program, hex dump of m/c listing program, the screen dump routine.

Mr Discrete's Car Alarm

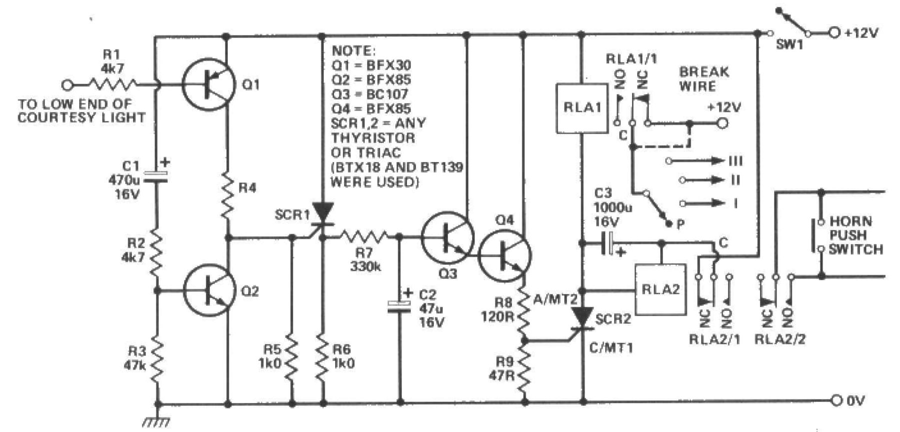
Guy Mellor
Macclesfield

Most designs for car alarms use IC timers such as 555s, 14528s or 74221s, but here is a design that can readily be made from discretes out of your junkbox.

On power up, C1 will pass current until fully charged, keeping Q2 turned on for about ten seconds. While Q2 is on, the gate of SCRI is low, ensuring that the SCR is off. In this period it is safe to get out of the car as any turn on signal by the courtesy light to Q1 will be ignored. Assuming the car door is now shut the state of circuit is Q1 and Q2 off. Any intruder opening the door now will turn Q1 on which will put the gate of SCRI high thus latching on. The voltage across C2 will now ramp up and the emitter of Q4 will follow it until sufficient potential appears on the gate of SCR2 which will latch RLA1 on, disabling ignition, and the RLA2 will click on and off, sounding the horn intermittently.

None of the parts used are critical so no buying-in should be necessary, with the possible exceptions of SW1 and RLA2. SW1 is specified as a keyswitch, but any ordinary switch with 1A contacts can be used if its location is concealed. Do not conceal the switch too well, because the circuit only gives you about 9 seconds to turn the alarm off before it does the old waking the neighbours act. RLA2 is specified as a 2PCO with 20A contacts. In the prototype I used an 11 pin relay with 10A contacts, but since 11 pin relays are 3PCO, two of the NO pairs were connected in parallel for RLA2/2. RLA2/1 is still just one pair.

SCR2 is specified as a thyristor but the acual device I used was a BT139 (which is a triac). This is because I happened to have a BT139 which wanted using, and in any case, either a thyristor or a triac will do. The same design criteria apply to SCRI.



The listing programme has both BASIC and machine code parts. Type in the BASIC section first and save it with SAVE "list" LINE 9968 and verify. Do not attempt to run it without the machine code or it will almost certainly be lost. Enter the machine code with a hex loader or similar and save this on tape immediately after the BASIC with SAVE "obj" CODE 65000,240, and verify. It should now be possible to autoload the whole programme with LOAD "list". Operating instructions will be displayed on the VDU.

The BASIC programme starts at line 9900 so any programme to be listed should have a lower maximum line number than this.

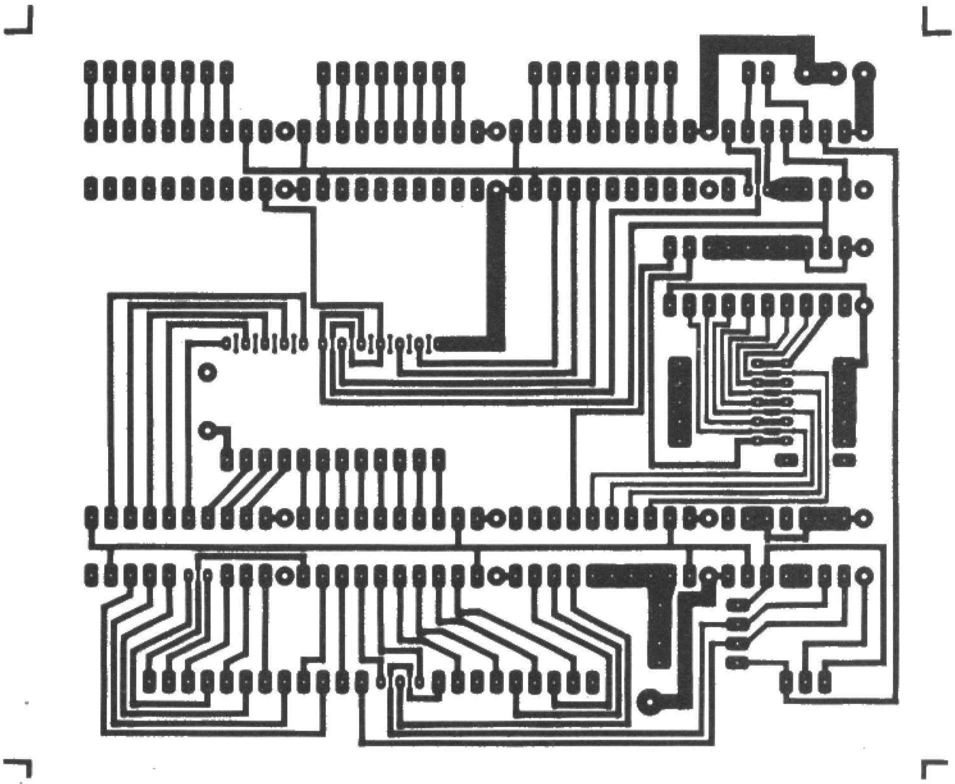
The screen dump routine is quite independent of the other and may be placed in any convenient location in memory as it has no internal absolute jumps.

It should be entered with a hex loader to say 65000, and then saved with SAVE "scr" 65000.

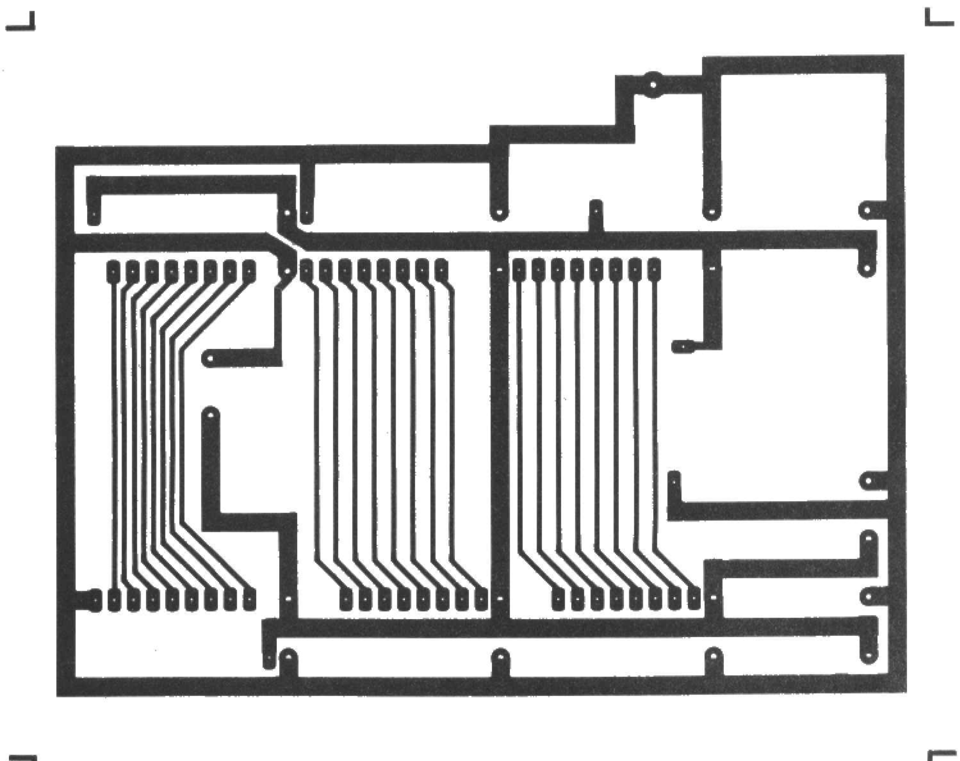
To call it from a BASIC programme, a line of the form RANDOMISE USR 65000 would be used.

For those who wish, I can provide a tape with both programmes at a cost of £3. Requests should be addressed to 14 Waverleigh Road, Cranleigh, Surrey.

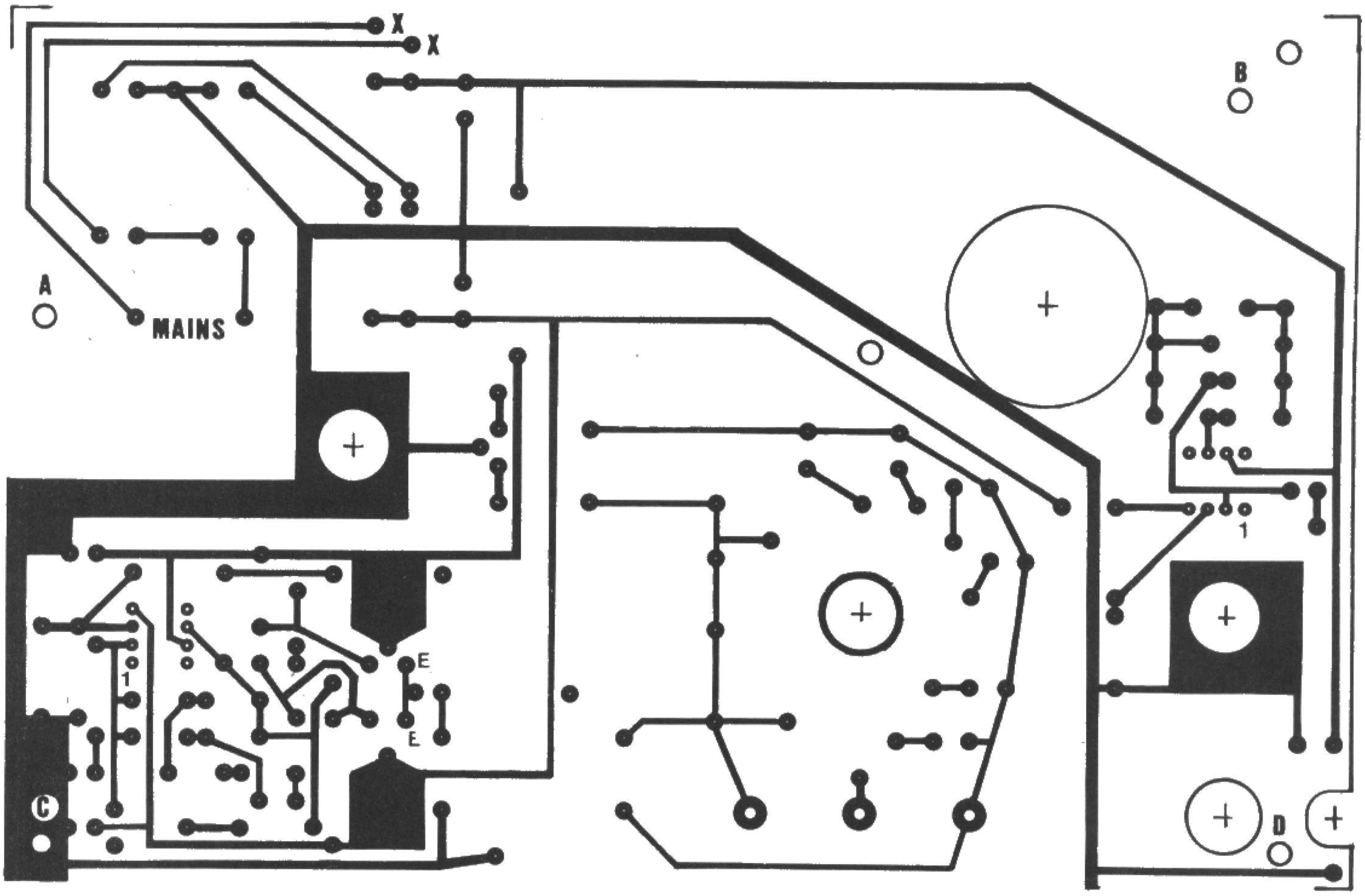
PCB FOIL PATTERNS

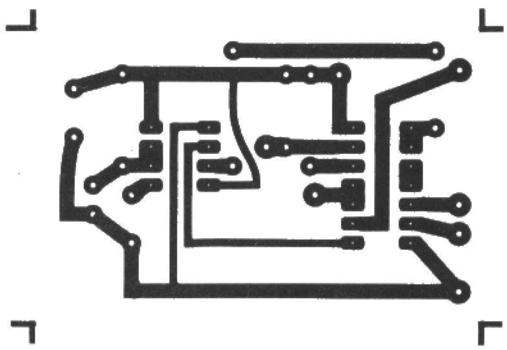


The top and bottom foils for the EPROM Emulator.



The foil pattern for the RCL Bridge PCB.





The EX42 Interface Board.

ETI PCB SERVICE

In order to ensure that you get the correct board, you must quote the reference code when ordering. The code can also be used to identify the year and month in which a particular project appeared: the first two numbers are the year, the third and fourth are the month and the number after the hyphen indicates the particular project.

Note that these are all the boards that are available — if it isn't listed, we don't have it.

Our terms are strictly cash with order — we do not accept official orders. However, we can provide a pro-forma invoice for you to raise a cheque against, but we must stress that the goods will not be dispatched until after we receive payment.

1981

- ☐ E/8109-1 Mains Audio Link (3 bds) ... 8.45
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- ☐ E/8110-2 Sound Bender ... 3.05
- ☐ E/8111-1 Voice Over Unit ... 4.57
- ☐ E/8111-3 Phone Bell Shifter ... 3.40
- ☐ E/8112-4 Component Tester ... 1.71

1982

- ☐ E/8202-2 Allez Cat Pest Repeller ... 1.93
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1983

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- ☐ E/8301-3 Programmable PSU ... 3.45
- ☐ E/8303-1 SoundBoard ... 12.83
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- ☐ E/8306-5 Atom Keypad ... 5.18
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- ☐ E/8312-3 Light Chaser (2 bds) ... 7.54
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1984

- ☐ E/8401-1 Vector Graphics ... 8.27
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- ☐ E/8402-2 MP (Modular Preamp) Disc input (mono) ... 3.73
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1985

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- ☐ E/8508-3 EPROM Emulator ... P.O.A.

How to order: indicate the boards required by ticking the boxes and send this page, together with your payment, to: ETI PCB Service, Argus Specialist Publications Ltd, 1 Golden Square, London W1R 3AB. Make cheques payable to ETI PCB Service. Payment in sterling only please. Prices subject to change without notice.

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PLAYBACK

A company called HHB were having a demonstration — something to do with digital audio, which the editor thought sounded interesting. It seemed worth dragging my lazy carcass down to the Smoke. While I was there, would I like to look at some new equipment that Marantz are meant to be exhibiting at the audio trade show?

After about an hour on the train going from the sticks to Euston station, and about twenty minutes travelling two stops on the tube, I arrived at HHB to find that a well organized exposition had just started. It was soon clear that HHB are a company who are firmly committed to the supply of digital audio recording equipment to professional studios.

Picture This

The equipment in question on this occasion is all Sony gear imported from Japan, and its function is to convert analogue audio signals into a digital form suitable for recording on a video cassette using an ordinary VCR. This is both more difficult and more useful than it may at first appear.

Because the video cassette machine requires a video signal to keep it in sync, the 16 bit digital audio has to be buffered to take account of the sync pulses (during which signals cannot be recorded) and then added to sync pulses to give a composite 'video' output. Once this process can be made to work reliably and economically, master tapes can be made and copied, yea unto the third and fourth generation, without degradation of quality.

Hi Numbers

The equipment which got the whole thing going properly were two processors intended for the hi-fi buff. For digital processors, these were and are very economically priced, though they cost more than the videocassette recorder they are intended to work with! The number of people willing to pay £700 for a PCM701ES, or £1,200 for a PCM F1, is clearly somewhat limited. Indeed, people who spend this much on an entire stereo system are probably an oppressed minority.

The people at HHB realised that, while this gear was a bit expensive for most hi-fi, it was very competitive as audio equipment. Its quality, in terms of frequency response and signal-to-noise ratio compared very favourably with analogue equipment.

At the same time, it was becoming clear that compact disc was here to stay, and that sooner or later this medium would find mass sales. In order to make good use of the quality available from this system, digital master tapes are essential. It would be absurd, after all, for the average domestic hi-fi user to have at their disposal equipment capable of better sound reproduction than is available from the master tapes.

The Hit Machine

Supporting HHB's claims about the quality of digital audio was a videotaped interview with Phil Collins, who takes his work home with him in the form of a PCM F1 processor. He commented that many musicians do not 'fine tune' the sound to the n-th degree because they know that by the time it gets onto the master disc no one will be able to hear it. He reckoned that in studios where digital recording is used, musicians can put in the effort to get sound quality spot on in the knowledge that people will have a chance to appreciate it. Well said. A far cry from the day when the LPs were so bad that you needed three or four tries to find a reasonable copy.

Maybe the record companies will go back to recycling the LP labels in order to lower the quality of LPs and 'encourage' people to change to the more expensive compact discs, but my guess is that if they make good use of digital recording technology they won't have to.

Statistics

This was done in part to publicise the fact that Sony have, largely due to the influence of HHB, restarted production of their economical digital encoding units. Just as HHB had made a start on renting and selling these units, Sony decided that the domestic market for these items was not big enough to support production. They dismantled the plant! HHB smartly bought up all the stocks they could get their hands on, and started trying to talk Sony into restarting production. They thought that the next item in the range, a large scale professional processor costing a cool £15,000 was too costly for a number of professional applications.

The percentage growth in the use of digital equipment is rapid. In 1982, an estimated 1% of recording studios used digital equipment. In 1983 the number rose to 15% and in 1984 reached 40%. HHB estimates (hopes) that the figure will soon be 75%. Of the studios using digital, HHB expect that 80% will be using F1 and 701 processors supplied by them.

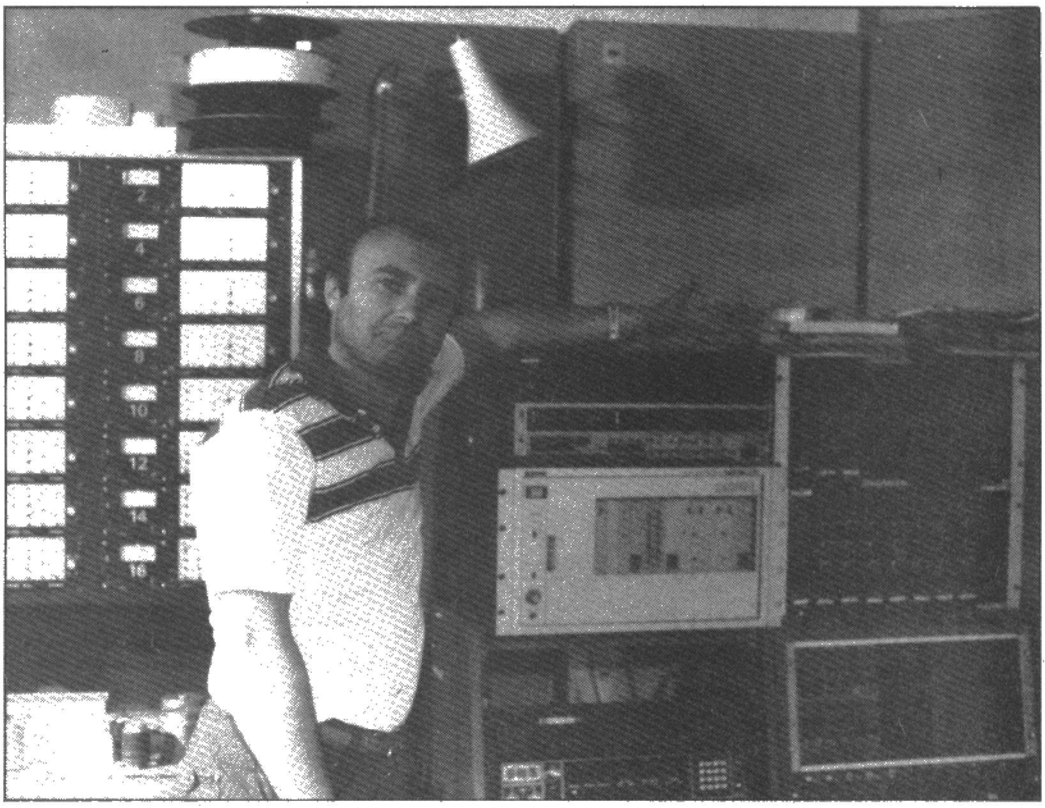
The growth in the use of digital technology in the recording studio runs parallel with the sales of compact discs in this country. These rose from ¼million in 1983 to nearly 1 million in 1984. The estimate for 1985 is 3 million.

CLUEdo

To assist the use of this digital equipment in recording studios, HHB have developed a computer-based editing aid, called Computer Logging Unit and Editor, which permits butt editing to the nearest frame. The only convenient means of editing with these cheap digital processors used to be by turning the signal into analogue form and back again.

Of course, editing to the nearest frame (or did they really mean field?) is not good enough to perform edits in the middle of a track on most rock music — doubly so at the PAL frame rate of 25 Hz as against the NTSC rate of 29.99 Hz. Still, different tracks can be joined together on one tape without the addition of noise and distortion, and the the information stored on disc by CLUE enables the recording engineer to work out what edits to carry out before transferring to more expensive equipment. CLUE controls the videocassette recorders for you, and finds the marked places, so there is time for the recording engineer to drink his coffee while the computer does some of the fiddly bits.

I must admit that I am moved to wonder why, with the buffering which is required anyway in the encoding system, they could not edit to the nearest line instead of



Easy lover loves his PCM 701ES and PCM 1610 digital sound processors.

the nearest frame, and simply detect the end of the next digital word to use as the actual edit point. Maybe it's more difficult than it appears, but to me it seems like spoiling the ship for ha'p'orth of tar. Perhaps the people at HHB, CLUEd up as they are, had a severely limited timescale and had to do what they could with equipment avialable off the shelf, and only minor mods.

All Gas And Gates

By no means all the applications for PCM 701 and F1 digital processors are in recording studios. The low background noise (approximately 6dB per bit or 6*16=96 dogbiscuits) make these digital processors useful for the accurate analysis required in speech recognition. British Telecom, among others, use the equipment for this purpose.

The Gas Board use the equipment to aid analysis of mechanical resonance in detecting metal fatigue. Nobody went into a lot of details about this, but apparently with analogue recording, the subtleties which actually indicate what is going on would be lost in the noise.

All this is a far cry from the origins of HHB's business. in 1976, when they started hiring out PA equipment for bands doing live performances.

Sansui and Sensibility

After this, the piece of trade show I visited was a slight anticlimax. The people on the Marantz stand told me that I needed to talk to the technical man — I realised that — but several people were waiting to see him already. Could I come back in half an hour? I conceded that I could and wandered off to see what else was around.

One of the first products I looked at (because it was near the door) was a Sansui digital encoder designed to record audio on a VCR. This is definitely intended for the domestic market, as it only uses 14 bits rather than the 16 used by the Sony equipment. This would give a theoretical signal to noise ratio of 84dB at best, which is still good compared with other domestic recording equipment. The encoder has the advantage that it can record successfully on video recorders running at half speed. Thus, on VCRs with this extended play mode, up to eight hours of recording are possible on one tape. I wonder how bad the dropouts are in this mode, and what effect they have on the sound?

Much of the equipment on the Sansui display looked similar to that available in most hifi shops, but there were some novel items. One was a graphic equaliser incorporating remote control, and a bar display of settings. The remote control box slides into the front of the unit to work as the local controller if required. This unit formed part of a rack system, at the top of which was a stereo amplifier featuring what looked like a video game display. It was actually the function indicator and power level meter.

On the left, a parametric equaliser control panel looked like mission control but was well laid out and should be easy to use. The whole assembly, including tuner, dual cassette deck, and computerised turntable, is called an 'Intelligent Super Compo' but I reckon it's the operator who has to be intelligent. With two types of equaliser to set for the right frequency response it is definitely for the initiated.

Round and Surround

Back to Marantz. The technical man is tied up and could I come back a bit later? Grumble. Oh well, just one more time. The question is, if he is in that much demand, why only one technical man?

A bit later he is still occupied and my feet are suffering from the strain so its down the road to the ETI offices for a sit down and a talk to the editor. A phone call to the Marantz offices resulted in a promise of information.

Sure enough, the man who had been in such heavy demand telephoned me a few days later to give me the lowdown on their new products. So new are they, that he had not had a chance to try them out properly himself before the show. The most interesting one is the Dolby surround sound decoder. It was news to met that rear channel information is encoded onto most prerecorded stereo videocassettes. The surround decoder allows the viewer to make use of this information, and it includes a stereo amplifier, so just add speakers and sit back.

It might be a bit unnerving to hear the spaceship roar overhead while watching 'Star Wars' on a small screen, but people who hire videocassettes of a spectacular nature may often be very interested, particularly considering the £129 price tag.

Andrew Armstrong

OPEN CHANNEL

Advanced Micro Devices (AMD) has recently announced its intention to sample a chip set later this year, for integrating the simultaneous transmission, in digital form, of voice and data along a single telephone line. Such a chip set brings us one step nearer to the total integration of voice and data communications into one single network, as envisaged in the Integrated Services Digital Network (ISDN)

Chips With Everything

Although still a long way off, the ISDN will eventually replace the existing telephone network and many data networks too. It will be a purely digital network, and so each telephone terminal must be capable of converting the analogue voice signals to a digital form before transmission, and reconverting received digital signals into sound. Alongside the transmitted digital sound will be the capability to transmit data, too, at a fairly high rate — in the region of 64,000 bits/sec.

For these purposes, some quite complex electronic circuits will be required, within each telephone terminal and within the many existing exchanges throughout the land; and of course the only way of approaching the problem is to design some chips to do the job. A number of semiconductor manufacturers are currently working on the designs.

The AMD chips set comprises five chips; the first two of which are the devices needed in the user's telephone terminal, the remaining devices are for exchanges. The company is to be congratulated for taking this brave step, given that worldwide standards are not yet finalised.

It really is about time that some of the governing bodies of the telecommunications world got their act together in this field. After all, how long do we want to be saddled with inferior data communications, at least when connected via the existing telephone network? It is rather archaic that to transmit data between telephone users we have to resort to devices which convert the digital data into analogue signals for transmission — modems. They're not exactly fast and they're certainly pricey.

The latest modem to hit the streets (in mid-May) follows CCITT Recommendation V32, which enables its use over ordinary dial-up telephone lines to a speed of only 9600bits/sec, at a cost of around £3000. Chicken feed? Hardly!

True, there are digital options such as Packet Switchstream, but they're costly too.

Pie in the Sky

Meanwhile, back to my favourite subject — or at least it seems to be my favourite subject; I've featured it quite regularly over the last few months — satellite television.

After long hassles over costings and finance, direct broadcasting by satellite (DBS) looks as if it may still get off the ground, if a little shakily. Only days before penning this column, the news broke that Unisat, the organisation which hopes to provide the satellites to be used, has finally retendered at a much lower price.

The Club of 21 (the operating consortium) appears to have won the round, after its gamble not to commit itself. Its argument was that Unisat's price was too high. Unisat finally appears to have agreed, and has given a number of options to the Club of 21, one of which is a much lower costing of (only?) £290m over 10 years.

That option may not, of course, be the one which the Club of 21 picks, and it's unclear at the time of writing what the other options are .. watch this space....

Money To Burn — But Whose?

Finally, a package has landed on my desk from the Department of Trade and Industry. Called 'The Development of the Liberalised Telecommunications Market in the United Kingdom — An Information Pack' it is an extremely glossy press and publicity gimmick which seems to have been sent out to just about anyone with anything to do with electronics, telecoms, or computers (the ETI office alone received two packs). Basically comprising issues six to fifteen of the Department's occasional news letter 'Ringing the Changes', it aspires to sum up all of the changes in the telecommunications field over the last couple of years, with regard to liberalisation. Very interesting, but how much did it all cost? Did it really do any good? Is that my income tax you're spending?

Keith Brindley ETI

SERVICE SHEET

NOTED & ADDED TO DEC 1984 ...

Enquiries

We receive a very large number of enquiries. Would prospective enquirers please note the following points:

● We undertake to do our best to answer enquiries relating to difficulties with ETI projects, in particular non-working projects, difficulties in obtaining components, and errors that you think we may have made. We do not have the resources to adapt or design projects for readers (other than for publication), nor can we predict the outcome if our projects are used beyond their specifications;

● Where a project has apparently been constructed correctly but does not work, we will need a description of its behaviour and some sensible test readings and drawings of oscillograms if appropriate. With a bit of luck, by taking these measurements you'll discover what's wrong yourself. Please do not send us any hardware (except as a gift!);

● Other than through our letters page, Read/Write, we will not reply to enquiries relating to other types of article in ETI. We may make some exceptions where the enquiry is very straightforward or where it is important to electronics as a whole;

● We receive a large number of letters asking if we have published projects for particular items of equipment. Whilst some of these can be answered simply and quickly, others would seem to demand the compiling of a long and detailed list of past projects. To help both you and us, we have made a full index of past ETI projects and features available (see under Backnumbers, below) and we trust that, wherever possible, readers will refer to this before getting in touch with us.

● **We will not reply to queries that are not accompanied by a stamped addressed envelope** (or international reply coupon). **We are not able to answer queries over the telephone.** We try to answer promptly, but we receive so many enquiries that this cannot be guaranteed.

● Be brief and to the point in your enquiries. Much as we enjoy reading your opinions on world affairs, the state of the electronics industry, and so on, it doesn't help our already overloaded enquiries service to have to plough through several pages to find exactly what information you want.

Subscriptions

The prices of ETI subscriptions are as follows:

UK:	£16.30
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Send your order and money to: ETI Subscriptions Department, Infonet Ltd, Times House, 179 The Marlowes, Hemel Hempstead, Hertfordshire, HP1 1BB (cheques should be made payable to ASP Ltd). Note that we run special offers on subscriptions from time to time (though usually only for UK subscriptions, sorry).

ETI should be available through newsagents, and if readers have difficulty in obtaining issues, we'd like to hear about it.

Backnumbers

Backnumbers of ETI are held for one year only from the date of issue. The cost of each is the current cover price of ETI plus 50p, and orders should be sent to: ETI Backnumbers Department, Infonet Ltd, Times House, 179 The Marlowes, Hemel Hempstead, Hertfordshire HP1 1BB. Cheques, postal orders, etc should be made payable to ASP Ltd. We suggest that you telephone first to make sure there are still stocks of the issue you require: the number is (0442) 48432. Please allow 28 days for delivery.

We would normally expect to have ample stocks of each of the last twelve issues, but obviously, we cannot guarantee this. Where a backnumber proves to be unavailable, or where the issue you require appeared more than a year ago, photocopies of individual articles can be ordered instead. These cost £1.50 (UK or overseas surface mail), irrespective of article length, but note that where an article appeared in several parts each part will be charged as one article. Your request should state clearly the title of the article you require and the month and year in which it appeared. Where an article appeared in several parts you should list these individually. An index listing projects only from 1972 to September 1984 was published in the October 1984 issue and can be ordered in the same way as any other photocopy. If you are interested in features as well as projects you will have to order an index covering the period you require only. A full index for the period from 1972 to March 1977 was published in the April 1977 issue, an index for April 1977 through to the end of 1978 was published in the December 1978 issue, the index for 1979 was published in January 1980, the 1980/81 index in January 1982, the 1982 index in December 1982, the 1983 index in January 1984 and the 1984 index in January 1985. Photocopies should be ordered from: ETI Photocopies, Argus Specialist Publications Ltd, 1 Golden Square, London W1R 3AB. Cheques, postal orders, etc should be made payable to ASP Ltd.

Write For ETI

We are always looking for new contributors to the magazine, and we pay a competitive page rate. If you have built a project or you would like to write a feature on a topic that would interest ETI readers, let us have a description of your proposal, and we'll get back to you to say whether or not we're interested and give you all the boring details. (Don't forget to give us your telephone number).

Trouble With Advertisers

So far as we know, all our advertisers work hard to provide a good service to our readers. However, problems can occur, and in this event you should:

1. Write to the supplier, stating your complaint and asking for a reply. Quote any reference number you may have (in the case of unsatisfactory or incomplete fulfilment of an order) and give full details of the order you sent and when you sent it.
2. Keep a copy of all correspondence.
3. Check your bank statement to see if the cheque you sent has been cashed.
4. If you don't receive a satisfactory reply from the supplier within, say, two weeks, write again, sending your letter recorded delivery, or telephone, and ask what they are doing about your complaint.

If you exhaust the above procedure and still do not obtain a satisfactory response from the supplier, then please drop us a line. We are not able to help directly, because basically the dispute is between you and the supplier, but a letter from us can sometimes help to get the matter sorted out. But please, don't write to us until you have taken all reasonable steps yourself to sort out the problem.

We are a member of the mail order protection scheme, and this means that, subject to certain conditions, if a supplier goes bankrupt or into liquidation between cashing your cheque and supplying the goods for which you have paid, then it may be possible for you to obtain compensation. From time to time, we publish details of the scheme near our classified ads, and you should look there for further details.

OOPS!

Corrections to projects are listed below and normally appear for several months. Large corrections are published just once, after which a note will be inserted to say that a correction exists and that copies can be obtained by sending in an SAE.

Digital Delay Line (December 1984 - January 1985)
In Fig. 6 on page 21 of the December issue, C19 and C20 are both 100uF. In Fig. 8 on page 62 of the January issue, C3 should be marked 33p. On the overlay diagram (Fig. 9, p.64), R37 is missing and should be connected between pin 3 of IC9 and the 0V line; R20 is missing and should be located in the holes immediately to the left of R18; R50 is missing and should be connected between pins 1 & 2 of IC14. Some components on the overlay have also been wrongly numbered:- C20 should be marked C19 and C21 should be marked C20; R12 (between ICs 5 & 6) should be marked R22; R48 should be R44, R49 should be R45, R57 should be R46, R51 should be R47, R50 should be R48, and R47 should be R49. The unmarked capacitor directly above what is now C19 is an un-numbered 100n ceramic. C30 does not appear on any diagram or parts list and this is correct. XX

On the digital board, IC24 in Fig.10 (p.55) is shown the wrong way around and IC35 at the bottom centre of the overlay should be marked IC25. The tracks to pins 8 and 9 of IC28 are the wrong way around but this should not affect the performance. It is quite easy to cut the tracks near the IC pins and connect across using wire links soldered into the adjacent through-board holes. D6 and R31 should be swopped over.

No frequency stabilising capacitor was included in the design but it has been found that in some cases the output frequency of IC30 is affected by stray capacitance and does not remain steady at 1MHz. This affects all the system timing. To overcome this problem, a 33p capacitor should be carefully soldered directly onto pins 6 and 7 of IC30 on the underside of the board.

Single Board Controller (March 1985)
There were a number of errors in the parts list. RP2 is listed as a 10k SIL pack but is actually four separate resistors, and the same applies to RP3. RP4 is also listed as a SIL pack but should consist of seven commoned resistors. R13 is always required, not just when a cassette interface is used as stated.

The Real Components (May 1985)
In Fig. 1 on page 20, the connections for the Texas L and 2N transistors are incorrectly shown. They should read B, C and E from the top. X

Heat Pen (June 1985)
The instruction in the penultimate paragraph on page 49 should read "... adjust RV2 for 2.73V ...", not 2.37V as stated. X

Low Cost Audio Mixer (June 1985)
In Fig. 6 on page 39, the PCB foil pattern has been incorrectly shown as though from the copper side. The board is shown correctly from the copper side in the foil pattern pages. In Fig. 10 on page 40, the positive power rail at lower left should be shown connected to pin 8 of the TL072s, IC1-5). X

Noise About Noise (July 1985)
In Fig. 5 on page 24, no connection should be shown between the cathode of the diode and the negative side of the 470u capacitor. X

Printer Buffer (July 1985)
The case specified is actually larger than the one used for the prototype. It will, of course, work perfectly well, but if you want a compact unit use a Verocase 202-21038H (180 x 120 x 65mm) rather than a Verocase 202-21035. The regulator IC17 should be bolted to the back of the case to provide heatsinking or, alternatively, fitted with a TO220 heatsink.

X = ALL READY ADDED TO MAGAZINES
XX = " " " " MAGAZINE

SCRATCH PAD

by Flea-Byte

To many readers, the abbreviation 'CIA' may be best known as one of a number of similar acronyms for devices used to interface microprocessors with the real world. To others, the three letters will be redolent of *unreality*.

The CIA (not just any old CIA, you understand) is the Central Intelligence Agency of the United States — one of eighteen such agencies operating in the home of the brave, land of the free. Known as 'the Company' to its employees, the CIA inhabits a strange world of fantasy spy games which it plays with deadly seriousness. You may recall that it was the CIA which once devised a plan to overthrow Fidel Castro by sending a squad of trained barbers over to Cuba to shave off his beard. The clean-shaven look, they reckoned in Langley, Virginia, would absolutely ruin Castro's street credibility! Exit one thorn in America's side — or (to be geographically more accurate) one pain in its backside.

We know this at least in part because the CIA maintains a curiously high profile — reckoning, perhaps, that either it is so powerful or its schemes are so lunatic that it will be all but invincible. Compared to the National Security Agency, the Department of Army Intelligence (a contradiction in terms according to Groucho Marx) or even the game old FBI, the CIA is a publicity-crazed strumpet.

So, scanning a journal called 'Mini-Micro Systems' that recently came my way, it came as no great surprise to find the CIA advertising for electronics engineers. These days, it would seem, barbers are out.

* * *

Don't all rush. There is a snag. You have to be an American citizen. It would probably help if you didn't serve on the USS Nimitz too. Oh, and you should have experience in Telecoms, Networking, Mini and Micro Systems, Logic Design or Firmware Development.

Once you've passed the interview and promised not to spy for anybody else, what delights can you expect? The Company may be crazy, but it is no joke. Among its more notable achievements has been the overthrow of legitimate governments in Iran, Guatemala, Vietnam, Cambodia and Chile. It has propped up dictatorial regimes across the world and the shadowy presence of the CIA can be detected wherever dirty tricks are done.

For your part, you could find yourself working on 'computer systems and communications efforts unique to the CIA', according to the recruitment ad. Read 'bugging, surveillance and electronic eavesdropping'. The Company promises 'excellent compensation, comprehensive benefits, the opportunity for foreign travel, and the chance to advance the state of the art while contributing to the Agency's mission'.

Or, to put it another way, you could journey to exotic little countries like Nicaragua and help to subvert genuine democracies. Alternatively, you might find yourself deep in the heart of the Soviet Union, or even listening in to overseas phone calls at Menwith Hill in North Yorkshire. And even if you do find yourself in a Russian jail serving a twenty-year term, you can console yourself with the thought of that 'excellent compensation' and those 'comprehensive benefits', like a pension when you get out and a pill to salve your conscience.

* * *

. . . Not Tobie

Of course, we don't have any spies in our country, except those working for the other side. And I wouldn't dream of suggesting that there's anything underhand in the way the police or security agencies deal with British dissidents. In fact, we don't even have any dissidents. Dissidents are all Russian. I mention this just to ensure that you don't get the wrong idea from the following little tale.

It seems that Tony Wilson, coordinator of the Electronics for Peace group and an electronics engineer in the pay of the government, was attending a meeting in Scotland recently with some people from the Scottish Campaign to Resist the Atomic Menace (SCRAM) and Scientists Against Nuclear Arms (SANA). Now Wilson has recently been voted Electronics Personality of the Year in a ballot organised by 'Electronics Times' (ETI, July 1985). It is believed that the ballot was fair and above board — it is thought that it was even postal — and Wilson was doubtless proud of the inexpensive little trophy he was awarded. Indeed, he had his trophy (known as a TOBIE) with him in his car. The strange thing is that the car was broken into and a bag containing the TOBIE and a few odds and ends was stolen. The thieves left some expensive electronic goodies also sitting in the car completely untouched. On the indubitable assumption that the runners-up in the TOBIE vote were not bad losers, there are two possible explanations for this curious theft. Either Wilson's award has annoyed somebody or Scottish thieves are notorious collectors of unsaleable baubles. Perhaps the Special Branch or MI5 will let me know if I've missed any pertinent points.

* * *

The Prince And The Leveller

'When His Royal Highness arrives,' said the man on the podium, 'you should all applaud but not stand up.' This was news to me — that you aren't required to rise when the Queen's consort enters a room. The room in question was the Great Hall at Westminster School and the occasion, the Young Electronics Designer of the Year awards, 1985, sponsored by Cirkit Holdings plc, the component company, and organised by Professor John Eggleston of Warwick University.

Ironically, nobody had bothered to check the PA, which was not working when I arrived and the only person to think of doing a sound-check was presenter Petula Clark, an old show-biz pro. We were introduced to Ronald and Richard Bulgin (or was it Doug and Dinsdale) of Bulgin, the company which owns Cirkit, and HRH duly arrived. Nobody stood up. On this occasion, the Prince had evidently not been engaged to speak, so he didn't say anything (at least, not so's I could hear). The tension mounted as we waited for the prizes to be announced. Eighteen finalists had been selected from 1,000 entrants (some being teams) and four finalists in both a senior and junior category would be rewarded with cash amounts of between £50 and £500 plus help with their careers and the chance to market their ideas. On top of that, Texas Instruments were offering a computer to the top school in the senior category and several calculators to the top school in the junior category.

The entries were judged for originality, construction, everyday usefulness and commercial feasibility. There seemed little doubt that the last was going to be the most important consideration and some sophisticated but no doubt expensive designs that had made it to the final stood little chance of winning. Successful electronics design is often a case of using simple ideas to perform original tasks at as little cost as possible. Brilliant design may reveal genius, but in the real world genius is often an encumbrance to profitability.

* * *

There were plenty of devices employing tried and trusted ideas in crafty disguises — the rain detectors and LDR light detectors of every elementary electronics course. One LDR circuit even won first prize in the senior section — Jonathan Kempster's audible spirit level, which used the liquid in an ordinary spirit level to break a beam to an LDR. And my personal favourite design, the Heath-Robinsonian egg-dipping controller gained first prize in the junior section for Daniel Rodenhurst with a very simple circuit. What pleased me most, however, was the number of designs aimed at helping the disabled. So take this column's independent awards Christopher Howard, for your toy for the severely handicapped, Russell Vowles for your infra-red remote controller for immboilised people, Andrew Burrows for your granny alarm buzzer and junior entrant Gareth Arthurs for your milk tester for the partially sighted.

As a matter of fact, the editor tells me that readers can expect to see one or two of the designs appearing in these pages. Watch out for them.

* * *

No Mean Time

Hughes Aircraft, the company founded by the reclusive and eccentric Howard Hughes, has announced the development of a hydrogen maser clock accurate to one second in 30 million years. This beats the previous record (held by caesium and rubidium gas-cell atomic clocks) by a factor of about 100. The clock, which originally weighed 500 kilos, has been miniaturised for use in satellite-based navigation systems. It now weighs around 20 kilos and is about the size of a portable television. This may well mean that nobody will have an excuse to be late for work any more.